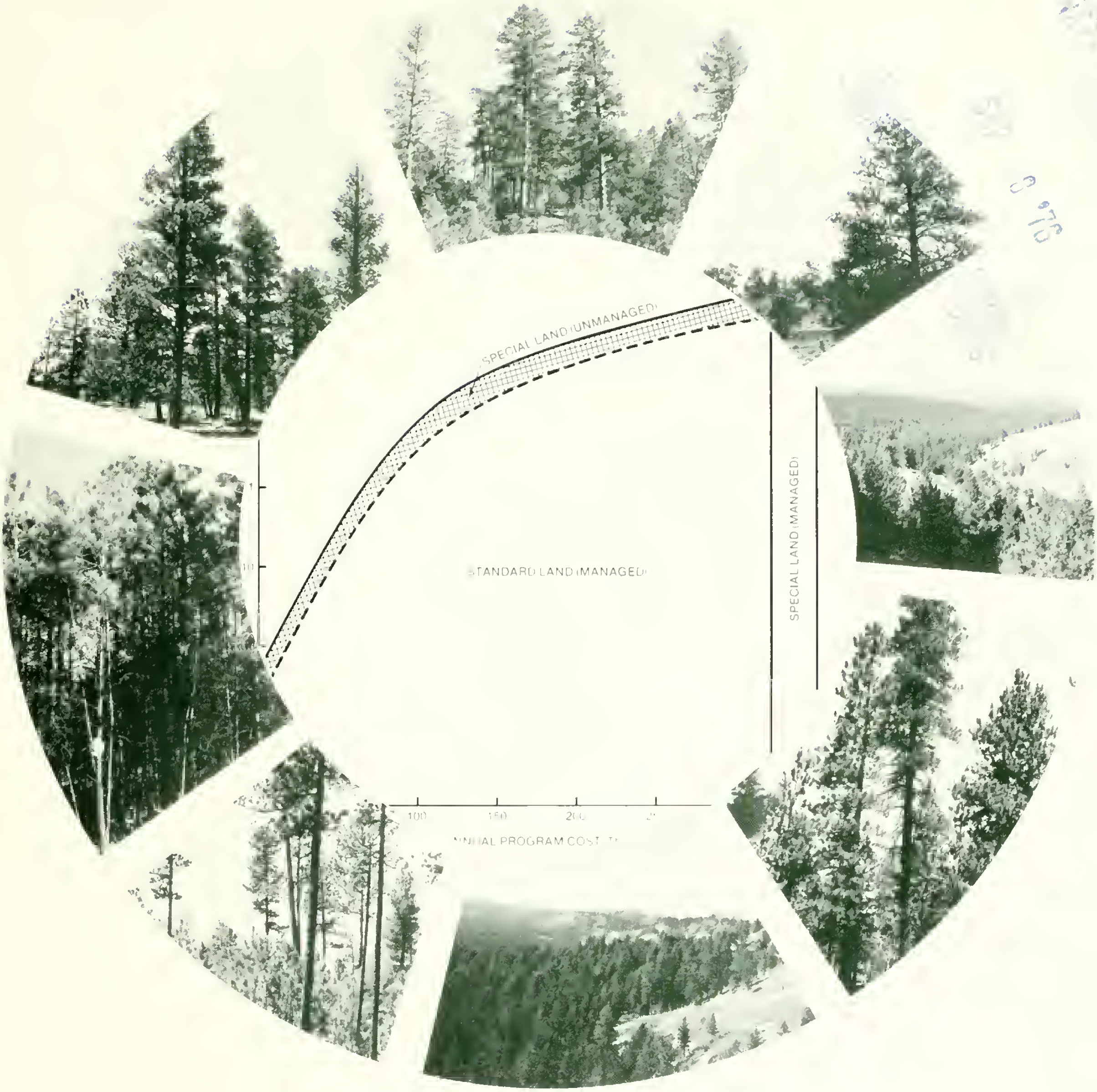


# ASSESSING THE TIMBER RESOURCE SITUATION ON A WORKING CIRCLE USING INVENTORY DATA

Alan W. Green

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INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION

# PREFACE

This publication is designed so that the reader with limited time can quickly obtain a summary of the complete paper by reading the highlights in the page margins and selected portions of the text.

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## ABSTRACT

Realistic projections of timber supplies require knowledge about the land's wood-growing capacity, constraints on the use of forest land for timber production, and the extent and condition of the existing timber resource. Timber inventory data can be used to estimate potential available output and to assess the existing resource in terms of general management needs and of its performance in producing usable wood.

# INTRODUCTION

An expanded program of intensive timber management is one way to increase wood supplies from a shrinking commercial forest land base. But, proposals to increase funding for an accelerated management program on National Forests are now being met with the question, "How much (more) wood will be produced with the money requested?"

There is considerable difference between the level of output it is possible to achieve and the level of output that might be economically desirable, considering the need for and the value of nontimber uses of the forest land and the condition and nature of the timber resource at hand. To answer the question then, the manager must have some information about (1) the productivity of the land, (2) the costs of management activities, (3) the impact of nontimber uses on availability of wood for harvest, and (4) the nature of the timber resource he has to work with.

The first three kinds of information enable the manager to estimate the sustainable output from his working circle under a fully managed or "regulated" condition. However, the actual near-future output will be determined by the character of his existing timber resource and the harvesting schedule used during the conversion period, after which the forest will be fully regulated.

Presently, harvesting schedules for National Forests are receiving a lot of attention. At issue is the Forest Service policy aimed at achieving a sustained and nondeclining even flow of timber from National Forest lands. This necessitates a somewhat longer time for liquidating old-growth stands than critics of the policy think is wise. A more rapid rate of old-growth liquidation could well result in a future "fall down," or drop, in sustainable output, which the Forest Service policy is designed to avoid. On the other hand, a greatly accelerated management program could increase total wood growth on a working circle and allow a more rapid cut of old-growth volume without a substantial future drop in sustainable output.

Many computerized models are used for determining the "best" harvesting schedules. All are based on some specific assumptions about factors such as present and prospective growth rates, volumes, and liquidation rates. Moreover, the assumptions used operate within and reflect the constraints set by basic policy objectives.

It is not the purpose of this paper to look at the propriety of any harvest scheduling scheme. Any such scheme is designed to offer the best chance to achieve the goal it is to serve. But, before assumptions are developed for use in generating a harvesting schedule, the manager should have some basic information about the biological possibilities for wood output, associated costs, and the nature of the resource stock he has to work with. Unless there is first a biological assessment of the resource situation, there is no foundation for a meaningful economic analysis for management planning purposes.

The data now being collected in timber inventories can be used to pinpoint problems the manager must deal with on the ground and in planning the management of the forest resource. Past efforts using inventory data for such purposes have been somewhat neglected.

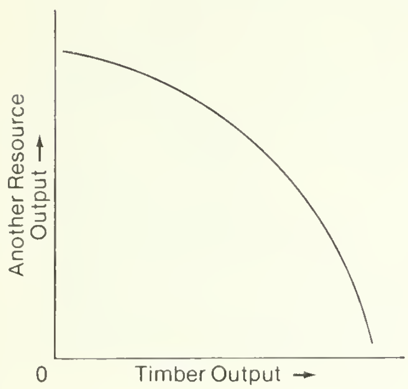
This paper discusses an approach, using timber inventory data, for looking at the biological side of timber production possibilities. It (1) demonstrates estimation of potential wood output in relation to nontimber-use demands on the forest land and management costs, and (2) discusses ways of identifying some problems and opportunities that must be dealt with in developing a harvest schedule and long-range management plan for eventually achieving that potential.

Data used are from the recently completed timber inventory of the Sitgreaves Working Circle, Apache-Sitgreaves National Forest in Arizona. The sampling scheme used was a stratified double sample (photo and field) with a random start, using a cluster of 10 sample points at each field location. Because ponderosa pine and Douglas-fir make up all but 1.3 percent of the commercial forest land and account for virtually all timber output from the working circle, only land occupied by these species or capable of growing them is considered in estimating potential output.

During the several years since the inventory data were compiled there have been some changes in land classification and attendant area, volume, and growth data. Therefore, basic data shown here should not be considered to be current official land and timber statistics for the Sitgreaves Working Circle. These data should be used only to follow the evaluation procedures.

# THE APPROACH

## Some Basics




JOINT PRODUCTION AND USE OF FOREST RESOURCES. If the objectives of using and managing publicly owned forest land are to be met, timber cannot be looked at in isolation. Some amounts of other resources are jointly produced or available with it and, presumably, some nontimber uses of forest land are necessary to meet those objectives.

Maximizing the output of timber will almost certainly result in less than maximum output of some other resources possible on the same land. Therefore, some knowledge of the trade-offs between timber and other possible resouree outputs is necessary for planning the management of the timber resource that will hopefully produce the desired output of timber and associated renewable resources.

QUESTIONS TO BE ANSWERED. A timber inventory and analysis should be designed to answer some basic questions:

WHAT COULD BE?

1. How much wood is it possible to produce on a commercial forest land base?

WHAT IS?

2. What is the current rate of wood production from this land?

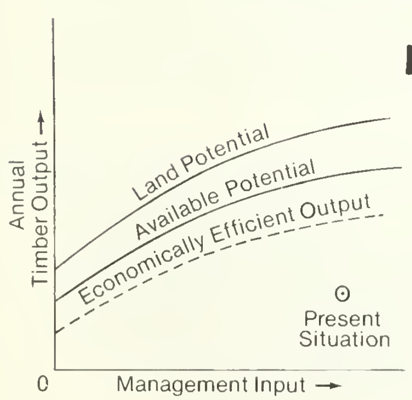
3. What must be done to achieve the potential?

WHAT SHOULD BE?

4. What are the relationships between timber production and other uses and values produced?

Answers to the first two questions provide the foundation for estimating the realistic future timber supplies available from the forest unit. Answers to questions 3 and 4 help define the future management strategies that will lead to achieving the target output.

## The Nature of the Analysis




PRODUCTION POSSIBILITIES. The thrust of the approach described here is to estimate the realistic potential timber output and to assess the problems and opportunities associated with achieving that potential.

Factors to be considered include the productive capacity of the land, constraints on timber management and harvesting activities, management costs, and the extent, nature, condition, and current performance of the existing resource with which the manager has to work. Defining economically efficient output is beyond the intent of this paper.

## Determinants of Timber Output

■ THREE BASIC FACTORS. The potential realizable output of timber is influenced primarily by:

- o Productivity of the land
- o Availability for harvest of the wood produced
- o The extent and effectiveness of management activities

□ LAND PRODUCTIVITY. Productivity classes assigned to commercial forest land indicate the quantity of wood (cubic feet per acre per year) fully stocked natural stands of a given species could produce. The terms yield-capability class, productive capacity, and site class have the same meaning.

Mean annual increment for natural stands could be maintained or exceeded through intensive management.

Productivity-class designation is keyed to the growth rate at culmination of mean annual increment in fully stocked stands and sets the upper limit of potential output from a given site under intensive management. Not considered are such management activities as fertilization or use of genetically superior strains of particular species.

Site-index values computed from site-tree data, yield estimates from normal-yield tables, and other data relating to productivity are used to estimate potential yield capability. Such yield estimates may or may not accurately reflect the true productivity of the land at any given location. A low stocking level at a location can result in a computed mean annual increment of less than the 20 cubic feet per acre per year required for a productive forest land classification. Therefore, information on factors affecting the stockability of the specific location is used to more accurately assign a productivity rating for that site. If the conditions of site and stand uniformity set by the developers of site-index curves and yield tables are not met, then logically some discounting or reduction of the potential yield estimate should be made for the location.

Site conditions can influence the number of trees it is possible to grow and therefore, the quantity of wood that can be grown.

Exposed bedrock, heavy clay soils, areas of severe erosion, and washes and arroyos, for example, can prohibit the establishment and growth of commercial tree species. But some understocked stands have the capability to grow commercial species, and the productive potential is greater than what is currently evident on the site.

The point is, the basic normal-yield estimates must be adjusted to accurately reflect productivity.

Not all the wood produced will be available.

□ AVAILABILITY. In the definition of commercial forest land, emphasis is on the land being both suitable and available for the production and harvest of wood products. Unfortunately, while land may be suitable and available for growing wood, some wood grown might not be available for use.

Without additional investments in roads, lack of access to otherwise usable timber is a constraint on availability. Or, if accessibility is no problem, multiple use, environmental, technological, and legal considerations result in constraints on the amount of wood that can be removed from certain areas. Such constraints can also increase the costs of management and harvesting activities.

Management costs money...

□ MANAGEMENT LEVELS. Management levels are important in developing estimates of potential timber output because of the costs associated with management activities. Costs for the same activity can differ because of the varying circumstances under which it is done. Planting may cost more on poor sites than on good sites; thinning in natural stands may cost more on good sites than on poor ones because of the number of trees to be removed.

and costs for the same activity can differ because of varying conditions at the worksite.

Available management money also affects the speed with which managers can reach the unit's potential output. Aside from liquidating or depleting growing stock, there are basically four ways in which timber output can be increased:

Management measures must be the right kind...

1. Shorten the regeneration period.
2. Increase growth rates. (Specific activities such as fertilization, use of genetically superior planting stock, and precommercial and commercial thinning fall into the general category of increasing growth rates.)
3. Reduce losses from insects, disease, and fire.
4. Improve utilization.

and be applied at the right time.

The manager is somewhat limited in his opportunities to apply techniques of management toward any of these four basic vehicles. Regeneration activities apply to nonstocked areas and to new areas as they are cut. Thinning is a live option only to the extent there are overstocked stands.

In working toward achievement of the output potential, the manager has only his existing timber resource; it is all he has to work with. The basic inventory data provide the manager with information about the condition of the timber resource and problem situations he must deal with in planning his management strategies.

The manager needs to know the situations to be dealt with to increase output.

Gross and net volume growth, mortality, diameter distribution, stocking levels, and other parameters that relate to the general management options can serve as signals, calling attention to situations needing some remedy before the potential output can be reached. In addition, information about certain attributes of the forest can help explain the existence of undesirable situations and often indicates an appropriate remedy.

# ESTIMATING THE POTENTIAL OUTPUT

## The Least Cost Path to Potential

Land plus management input minus constraints equals potential available output.

DEVELOPING AN OUTPUT CURVE. It is important to remember that this part of evaluating timber-production potential relates only to what the land could produce, given certain amounts of dollars for management activities and whatever management and land-use constraints are in force. How much wood might be harvested over a specified period if, beginning with bare land and a seed source, certain management activities were undertaken?

Potential output curve is neither a production curve nor a supply curve.

An output curve traces the eventual production at a number of management levels, once the forest unit is in a fully regulated condition. It does not define the most economically desirable budget level, which requires assigning per unit values of output.

There are many ways to develop an output curve. Computers offer a speedy method for summarizing pertinent information and, in some cases, for actually computing and even plotting the marginal cost-marginal output information that is the foundation of the curve.

Land classes reflect impacts on wood availability and on the the costs to produce it.

LAND CLASSES. The commercial forest land of the working circle inventoried was categorized into three land classes:

Standard.--Land available and operable now. No nontimber-use impacts affecting the growing costs or expected yields of timber.

Special.--Land available and operable now, but with ecological or other use constraints affecting the cost of growing timber, expected yield, or both.

Marginal.--Land potentially available and operable, or both, but not now scheduled for harvest because of excessive development costs, low product returns, or resource protection constraints.

Availability classes define the amount of impact on wood yields or on removals possible.

AVAILABILITY CLASSES. An availability class was designated for each of the various kinds of land included in each land class (table 1). Because the commercial forest land on the working circle is virtually all roaded, availability is a matter of constraints on removals related to the values of nontimber use. Using Standard Land as Availability Class I where full yields can be expected to be captured, other availability classes were defined in terms of the proportion (percent) of Standard Land yields expected, considering impacts of other uses. A total of five availability classes were recognized (tables 1 and 2).

Table 1.--*Definitions and components of the availability classes used*

| Land class | Availability class | Percent of standard land yield expected | Land included |
|---|---|---|---|
| Standard | I | 100 | All Standard Land |
| Special | I | 100 | Multiple use demonstration area |
| | II | 90 | Backdrop, scenic areas, roadside management areas |
| | III | 10 | Travel and water influence zones |
| | IV | 0 | Aztec lands[1] |
| Marginal | I | 100 | Inoperable[2] |
| | V | 50 | Steep slopes[2] |

[1]Lands recently acquired by the Forest, but without significant timber rights until as late as 1999.
[2]Presently unavailable with current logging techniques and a prudent operation.

Table 2.--*Area by land class, availability class, and productivity class*

| Availability class | Productivity class | Land Class: Standard | Special | Marginal | Total |
|---|---|---|---|---|---|
| | *Ft³/a/yr* | - - - - - - - - - - *Acres* - - - - - - - - - - | | | |
| I | 20-35 | 276,245 | 1,088 | 19,129 | 296,462 |
| | 36-50 | 58,382 | 272 | 4,553 | 63,207 |
| | 50+ | 19,143 | 14 | 2,047 | 21,204 |
| Total | | 353,770 | 1,374 | 25,729 | 380,873 |
| II | 20-35 | 0 | 10,228 | 0 | 10,228 |
| | 36-50 | 0 | 2,447 | 0 | 2,447 |
| | 50+ | 0 | 459 | 0 | 459 |
| Total | | 0 | 13,134 | 0 | 13,134 |
| III | 20-35 | 0 | 15,564 | 0 | 15,564 |
| | 36-50 | 0 | 3,095 | 0 | 3,095 |
| | 50+ | 0 | 1,093 | 0 | 1,093 |
| Total | | 0 | 19,752 | 0 | 19,752 |
| IV | 20-35 | 0 | 13,732 | 0 | 13,732 |
| | 36-50 | 0 | 2,216 | 0 | 2,216 |
| | 50+ | 0 | 836 | 0 | 836 |
| Total | | 0 | 16,784 | 0 | 16,784 |
| V | 20-35 | 0 | 0 | 2,365 | 2,365 |
| | 36-50 | 0 | 0 | 535 | 535 |
| | 50+ | 0 | 0 | 245 | 245 |
| Total | | 0 | 0 | 3,145 | 3,145 |
| Total | | 353,770 | 51,044 | 28,874 | 433,688 |

Marginal Land is separated into inoperable and steep slope areas, both presently unavailable with current logging techniques and prudent operation. However, in the event that balloon or helicopter logging should be introduced, the inoperable area could be fully utilized. Therefore, that area was put into Availability Class I to compute a potential yield. Management costs would be considerably higher for the area, of course.

Availability Class V consists of steep slope land that could not withstand full harvest and management activity even with aerial logging. It is estimated that only about 50 percent of the volume grown could be captured without irreparable damage to the resource (table 1).

Four general levels of management were used to estimate potential output...

□ MANAGEMENT LEVELS. Four levels of management were used in estimating wood production. Those considered can be defined in terms of regeneration effort and stocking control:

| Management level | Regeneration effort | Stocking control |
|---|---|---|
| 1 | NO | NO |
| 2 | NO | YES |
| 3 | YES | NO |
| 4 | YES | YES |

Obviously, one always has the choice of doing nothing following harvesting of mature timber. Beyond that, one can shorten the regeneration period or shorten the precommercial growing period by some activities or combination of activities, and thereby increase the total yield over some specified time frame.

but more could be used.

Regeneration effort in Management Level 3 indicates natural regeneration with site-preparation work in addition to routine logging disturbance and for which some cost would be incurred. In Management Level 4, partial or complete planting of the cutover area is indicated.

Stocking control indicates only precommercial thinning at some cost; however, it is assumed that if precommercial thinning were done, commercial thinning would also be undertaken.

Cost and yield estimates associated with different management levels are needed for each

□ COST AND YIELD ESTIMATES. Basic cost and yield estimates required to approximate the potential output curve are illustrated in appendix tables 12, 13, and 14. Many formats could be used to display such data; however, because this study was limited primarily to two species under common

land class and availability class.

management regimens, the data have been basically separated by land class only. Whatever explanation of data generation and use is needed can be made by using appendix table 12 for Standard Land. Further disaggregation by stand size and other descriptive features is at this point unnecessary because we are looking only at the potential of the land to produce and at constraints on removals.

The inventory was designed to separate four productivity classes. However, examination of the data showed most of the land fell into the 20 to 50 cubic foot per acre per year category, a situation that would not allow any meaningful evaluation of management levels by site quality. Even by splitting the 20 to 50 cubic foot productivity class, nearly 80 percent of the Standard Land is low site (20 to 35 cubic feet per acre per year). The number and magnitude of productivity classes appropriate for such evaluations will naturally vary in relation to the character of the forest land under study.

Use the best data available to make the estimates.

The best information available for the working circle inventoried indicated that the average productivity of the 20 to 35 cubic foot class probably was about 33 cubic feet per acre per year. Averages for the other classes were assigned on the basis of site-index data converted to a productivity rating in cubic feet. It appears likely that productivity of forest land on the working circle inventoried was somewhat understated as a result of the manner in which some of the inventory data were collected. Because the data are used for illustration purposes only, this does not detract from the methods described. However, the importance of reliable land productivity data cannot be overemphasized.

The on-site treatment costs were developed from average costs experienced by the Forest over the past several years; all overhead is excluded. An adjustment was made for inflation and some best estimates were made of increased management costs for areas, such as travel and water influence zones and backdrop and scenic areas, where virtually all traces of forest management activities probably would have to be erased.

The cost figures in columns 13 and 14 in appendix tables 12, 13, and 14 are important for the final calculations of output curve data; they are the basis for ranking the timber production opportunities by cost per unit to develop cost-output information that will provide the foundation for defining the output curve.

The cost per acre per year for management, and the expected yields per acre per year were used to develop table 3 and appendix tables 15 and 16. Cost per unit is converted to cost

per thousand cubic feet for convenience and clarity, and a ranking is made (col. 8, table 3 and appendix tables 15 and 16) of the management options in terms of cost per thousand cubic feet of wood produced.

Table 3.--*Area and expected costs and yields by productivity class*[1]

STANDARD LAND

| Productivity class ($ft^3$/acre/yr) | Acres (1) | Mgt. level (2) | Annual mgt. cost per acre (3) | Annual yield per acre (4) | Management cost per year (3)x(1) (5) | Yield expected per year: (4)x(1) (6) | Cost per M cubic feet (5)÷(6) (7) | Rank (8) |
|---|---|---|---|---|---|---|---|---|
| | | | $ | $ft^3$ | $ | $ft^3$ | $ | |
| 20-35 | 276,245 | 1 | 0 | 19.2 | 0 | 5,303,904 | 0 | 1 |
| | | 2 | 0.21 | 26.8 | 58,011 | 7,403,366 | 7.84 | 6 |
| A | | 3 | .21 | 24.2 | 58,012 | 6,685,129 | 8.68 | 8 |
| | | 4 | .96 | 33.0 | 265,195 | 9,116,085 | 29.09 | 10 |
| 36-50 | 58,382 | 1 | 0 | 35.4 | 0 | 2,066,723 | 0 | 1 |
| | | 2 | .29 | 43.1 | 16,931 | 2,516,264 | 6.73 | 5 |
| B | | 3 | .11 | 38.8 | 6,422 | 2,265,222 | 2.84 | 3 |
| | | 4 | .82 | 48.0 | 47,873 | 2,802,336 | 17.08 | 9 |
| 50+ | 19,143 | 1 | 0 | 48.2 | 0 | 922,693 | 0 | 1 |
| | | 2 | .38 | 61.1 | 7,274 | 1,169,637 | 6.22 | 4 |
| C | | 3 | .06 | 50.4 | 1,149 | 964,807 | 1.19 | 2 |
| | | 4 | .52 | 65.0 | 9,954 | 1,244,295 | 8.00 | 7 |
| Total | 353,770 | | | | | | | |

[1]The same information for Special and Marginal Lands is found in appendix tables 15 and 16.

[2]Lettered productivity class designations (A, B, and C) are shown so they maybe related to similar designations used in computing the information for the 64 management combinations (table 4).

The manager can do nothing, or something...

□ COSTS AND YIELDS. Several points need to be made about developing the cost-output values. First of all, it is obvious that if nothing is done, after harvest, wood will be produced anyway. It will cost nothing but time and worry.

but he can do only one level of management at a time on the same land.

Secondly, only one level of management can be undertaken on land of a given productivity class at one time. To build the output curve then, the beginning point is the expected yield available at no cost. By summing the expected yields from Management Level 1 in each land-productivity class and availability class for Standard and Special Land (appendix

tables 15 and 16), the annual output with no management cost is found. To increase output, expenditures for management are required.

□ AN APPROXIMATE CURVE. A reasonable approximation of the output curve for Standard Land can be made by assuming that all acres in a productivity class will be managed at the same level and successively adding in the next most cost-effective opportunity as indicated by the ranking in column 8, table 3. As this is done, however, the management level previously used in the productivity class must be removed as the new one is included. The marginal costs and yields of the new option over the previous one are calculated. When all nine options to spend money have been used, the marginal costs and yields are cumulatively summed and the points plotted. This method results in a curve accurate at both ends, but too low in the middle.

The output curve is built on the marginal output and costs for successively more expensive management undertakings.

A more accurate curve requires that all possible combinations of options be ranked and marginal costs and output computed. On Standard Land, for example, there are four management levels for each of three productivity classes (sets). Because three management options must be used at a time, one in each productivity class, there are 64 combinations to consider. The number of combinations is:

$$\left[ \frac{n!}{r!(n-r)!} \right]^k$$

where

n is the number of management levels (in a set)
r is the number to be taken at a time
k is the number of productivity classes (or sets).

A small computer program for listing all possible combinations and computing the costs and yields saves many hours (table 4).

Several computerized resource allocation models are now in use that spell out directly the most desirable timber output level over the next 10 to 12 decades. The output levels indicated are desirable only in relation to the criterion of goodness used to make the decision, however. There are many assumptions about values of timber, other associated resources, or both, in such models that are open to question for any particular stand or working circle to which they are applied.

It would seem to be premature to define "desirable" output and to use it as a production target without knowing first what is possible and the condition of the resource in terms of the likelihood of achieving it in the near future.

Table 4.--*Costs, yields, and per unit costs of 64 possible combinations of management levels on the three productivity classes of Standard Land*

| Productivity class | | | Treatment costs | | | | Annual yield | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Productivity class | | | | Productivity class | | | | |
| A (20-35) | B (36-50) | C (50+) | A | B | C | Total | A | B | C | Total | Cost/M $ft^3$ |
| *Management levels* | | | $ | | | | $Ft^3$ | | | | $ |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 5,303,904 | 2,066,723 | 922,693 | 8,293,319 | 0 |
| 1 | 1 | 2 | 0 | 0 | 7,274 | 7,274 | 5,303,904 | 2,066,723 | 1,169,637 | 8,540,264 | 0.85 |
| 1 | 1 | 3 | 0 | 0 | 1,149 | 1,149 | 5,303,904 | 2,066,723 | 964,807 | 8,335,434 | .14 |
| 1 | 1 | 4 | 0 | 0 | 9,954 | 9,954 | 5,303,904 | 2,066,723 | 1,244,295 | 8,614,922 | 1.16 |
| 1 | 2 | 1 | 0 | 16,931 | 0 | 16,931 | 5,303,904 | 2,516,264 | 922,693 | 8,742,861 | 1.94 |
| 1 | 2 | 2 | 0 | 16,931 | 7,274 | 24,205 | 5,303,904 | 2,516,264 | 1,169,637 | 8,989,806 | 2.69 |
| 1 | 2 | 3 | 0 | 16,931 | 1,149 | 18,079 | 5,303,904 | 2,516,264 | 964,807 | 8,784,975 | 2.06 |
| 1 | 2 | 4 | 0 | 16,931 | 9,954 | 26,885 | 5,303,904 | 2,516,264 | 1,244,295 | 9,064,463 | 2.97 |
| 1 | 3 | 1 | 0 | 6,422 | 0 | 6,422 | 5,303,904 | 2,265,222 | 922,693 | 8,491,818 | .76 |
| 1 | 3 | 2 | 0 | 6,422 | 7,274 | 13,696 | 5,303,904 | 2,265,222 | 1,169,637 | 8,738,763 | 1.57 |
| 1 | 3 | 3 | 0 | 6,422 | 1,149 | 7,571 | 5,303,904 | 2,265,222 | 964,807 | 8,533,933 | .89 |
| 1 | 3 | 4 | 0 | 6,422 | 9,954 | 16,376 | 5,303,904 | 2,265,222 | 1,244,295 | 8,813,421 | 1.86 |
| 1 | 4 | 1 | 0 | 47,873 | 0 | 47,873 | 5,303,904 | 2,802,336 | 922,693 | 9,028,933 | 5.30 |
| 1 | 4 | 2 | 0 | 47,873 | 7,274 | 55,148 | 5,303,904 | 2,802,336 | 1,169,637 | 9,275,877 | 5.95 |
| 1 | 4 | 3 | 0 | 47,873 | 1,149 | 49,022 | 5,303,904 | 2,802,336 | 964,807 | 9,071,047 | 5.40 |
| 1 | 4 | 4 | 0 | 47,873 | 9,954 | 57,828 | 5,303,904 | 2,802,336 | 1,244,295 | 9,350,535 | 6.18 |
| 2 | 1 | 1 | 58,011 | 0 | 0 | 58,011 | 7,403,366 | 2,066,723 | 922,693 | 10,392,781 | 5.58 |
| 2 | 1 | 2 | 58,011 | 0 | 7,274 | 65,286 | 7,403,366 | 2,066,723 | 1,169,637 | 10,639,726 | 6.14 |
| 2 | 1 | 3 | 58,011 | 0 | 1,149 | 59,160 | 7,403,366 | 2,066,723 | 964,807 | 10,434,896 | 5.67 |
| 2 | 1 | 4 | 58,011 | 0 | 9,954 | 67,966 | 7,403,366 | 2,066,723 | 1,244,295 | 10,714,384 | 6.34 |
| 2 | 2 | 1 | 58,011 | 16,931 | 0 | 74,942 | 7,403,366 | 2,516,264 | 922,693 | 10,842,323 | 6.91 |
| 2 | 2 | 2 | 58,011 | 16,931 | 7,274 | 82,217 | 7,403,366 | 2,516,264 | 1,169,637 | 11,089,268 | 7.41 |
| 2 | 2 | 3 | 58,011 | 16,931 | 1,149 | 76,091 | 7,403,366 | 2,516,264 | 964,807 | 10,884,437 | 6.99 |
| 2 | 2 | 4 | 58,011 | 16,931 | 9,954 | 84,897 | 7,403,366 | 2,516,264 | 1,244,295 | 11,163,925 | 7.60 |
| 2 | 3 | 1 | 58,011 | 6,422 | 0 | 64,433 | 7,403,366 | 2,265,222 | 922,693 | 10,591,280 | 6.08 |
| 2 | 3 | 2 | 58,011 | 6,422 | 7,274 | 71,708 | 7,403,366 | 2,265,222 | 1,169,637 | 10,838,225 | 6.62 |
| 2 | 3 | 3 | 58,011 | 6,422 | 1,149 | 65,582 | 7,403,366 | 2,265,222 | 964,807 | 10,633,395 | 6.17 |
| 2 | 3 | 4 | 58,011 | 6,422 | 9,954 | 74,388 | 7,403,366 | 2,265,222 | 1,244,295 | 10,912,883 | 6.82 |
| 2 | 4 | 1 | 58,011 | 47,873 | 0 | 105,885 | 7,403,366 | 2,802,336 | 922,693 | 11,128,395 | 9.51 |
| 2 | 4 | 2 | 58,011 | 47,873 | 7,274 | 113,159 | 7,403,366 | 2,802,336 | 1,169,637 | 11,375,339 | 9.95 |
| 2 | 4 | 3 | 58,011 | 47,873 | 1,149 | 107,033 | 7,403,366 | 2,802,336 | 964,807 | 11,170,509 | 9.58 |
| 2 | 4 | 4 | 58,011 | 47,873 | 9,954 | 115,839 | 7,403,366 | 2,802,336 | 1,244,295 | 11,449,997 | 10.12 |
| 3 | 1 | 1 | 58,011 | 0 | 0 | 58,011 | 6,685,129 | 2,066,723 | 922,693 | 9,674,544 | 6.00 |
| 3 | 1 | 2 | 58,011 | 0 | 7,274 | 65,286 | 6,685,129 | 2,066,723 | 1,169,637 | 9,921,489 | 6.58 |
| 3 | 1 | 3 | 58,011 | 0 | 1,149 | 59,160 | 6,685,129 | 2,066,723 | 964,807 | 9,716,659 | 6.09 |
| 3 | 1 | 4 | 58,011 | 0 | 9,954 | 67,966 | 6,685,129 | 2,066,723 | 1,244,295 | 9,996,147 | 6.80 |
| 3 | 2 | 1 | 58,011 | 16,931 | 0 | 74,942 | 6,685,129 | 2,516,264 | 922,693 | 10,124,086 | 7.40 |
| 3 | 2 | 2 | 58,011 | 16,931 | 7,274 | 82,217 | 6,685,129 | 2,516,264 | 1,169,637 | 10,371,031 | 7.93 |
| 3 | 2 | 3 | 58,011 | 16,931 | 1,149 | 76,091 | 6,685,129 | 2,516,264 | 964,807 | 10,166,200 | 7.48 |
| 3 | 2 | 4 | 58,011 | 16,931 | 9,954 | 84,897 | 6,685,129 | 2,516,264 | 1,244,295 | 10,445,688 | 8.13 |
| 3 | 3 | 1 | 58,011 | 6,422 | 0 | 64,433 | 6,685,129 | 2,265,222 | 922,693 | 9,873,043 | 6.53 |
| 3 | 3 | 2 | 58,011 | 6,422 | 7,274 | 71,708 | 6,685,129 | 2,265,222 | 1,169,637 | 10,119,988 | 7.09 |
| 3 | 3 | 3 | 58,011 | 6,422 | 1,149 | 65,582 | 6,685,129 | 2,265,222 | 964,807 | 9,915,158 | 6.61 |
| 3 | 3 | 4 | 58,011 | 6,422 | 9,954 | 74,388 | 6,685,129 | 2,265,222 | 1,244,295 | 10,194,646 | 7.30 |
| 3 | 4 | 1 | 58,011 | 47,873 | 0 | 105,885 | 6,685,129 | 2,802,336 | 922,693 | 10,410,158 | 10.17 |
| 3 | 4 | 2 | 58,011 | 47,873 | 7,274 | 113,159 | 6,685,129 | 2,802,336 | 1,169,637 | 10,657,102 | 10.62 |
| 3 | 4 | 3 | 58,011 | 47,873 | 1,149 | 107,033 | 6,685,129 | 2,802,336 | 964,807 | 10,452,272 | 10.24 |
| 3 | 4 | 4 | 58,011 | 47,873 | 9,954 | 115,839 | 6,685,129 | 2,802,336 | 1,244,295 | 10,731,760 | 10.79 |
| 4 | 1 | 1 | 265,195 | 0 | 0 | 265,195 | 9,116,085 | 2,066,723 | 922,693 | 12,105,500 | 21.91 |
| 4 | 1 | 2 | 265,195 | 0 | 7,274 | 272,470 | 9,116,085 | 2,066,723 | 1,169,637 | 12,352,445 | 22.06 |
| 4 | 1 | 3 | 265,195 | 0 | 1,149 | 266,344 | 9,116,085 | 2,066,723 | 964,807 | 12,147,615 | 21.93 |
| 4 | 1 | 4 | 265,195 | 0 | 9,954 | 275,150 | 9,116,085 | 2,066,723 | 1,244,295 | 12,427,103 | 22.14 |
| 4 | 2 | 1 | 265,195 | 16,931 | 0 | 282,126 | 9,116,085 | 2,516,264 | 922,693 | 12,555,042 | 22.47 |
| 4 | 2 | 2 | 265,195 | 16,931 | 7,274 | 289,400 | 9,116,055 | 2,516,264 | 1,169,637 | 12,801,987 | 22.61 |
| 4 | 2 | 3 | 265,195 | 16,931 | 1,149 | 283,275 | 9,116,085 | 2,516,264 | 964,807 | 12,597,156 | 22.49 |
| 4 | 2 | 4 | 265,195 | 16,931 | 9,954 | 292,080 | 9,116,085 | 2,516,264 | 1,244,295 | 12,876,644 | 22.68 |
| 4 | 3 | 1 | 265,195 | 6,422 | 0 | 271,617 | 9,116,085 | 2,265,222 | 922,693 | 12,303,999 | 22.08 |
| 4 | 3 | 2 | 265,195 | 6,422 | 7,274 | 278,892 | 9,116,085 | 2,265,222 | 1,169,637 | 12,550,944 | 22.22 |
| 4 | 3 | 3 | 265,195 | 6,422 | 1,149 | 272,766 | 9,116,085 | 2,265,222 | 964,807 | 12,346,114 | 22.09 |
| 4 | 3 | 4 | 265,195 | 6,422 | 9,954 | 281,572 | 9,116,085 | 2,265,222 | 1,244,295 | 12,625,602 | 22.30 |
| 4 | 4 | 1 | 265,195 | 47,873 | 0 | 313,068 | 9,116,085 | 2,802,336 | 922,693 | 12,841,114 | 24.38 |
| 4 | 4 | 2 | 265,195 | 47,873 | 7,274 | 320,343 | 9,116,085 | 2,802,336 | 1,169,637 | 13,088,058 | 24.48 |
| 4 | 4 | 3 | 265,195 | 47,873 | 1,149 | 314,217 | 9,116,085 | 2,802,336 | 964,807 | 12,883,228 | 24.39 |
| 4 | 4 | 4 | 265,195 | 47,873 | 9,954 | 323,023 | 9,116,085 | 2,802,336 | 1,244,295 | 13,162,716 | 24.54 |

If these 64 possible combinations are ranked in order of their per unit cost from lowest to highest, plotting total costs and yields for each combination will produce the potential output curve.

The flattening of the curve reflects smaller gains in output as management dollar investments increase...

That is, the cost per unit of wood produced is getting larger.

The potential output curve for the working circle inventoried (fig. 1) begins with the option of no management. This would ultimately result in about 8.3 million cubic feet from Standard Land and approximately 361,000 cubic feet from Special Lands (appendix table 15). As the most cost-effective options to spend money are substituted into the curve, it is seen that under full management, and at an on-site cost of approximately $323,000, about 13.6 million cubic feet of wood can be produced annually, including the wood available from Special Land at no cost (appendix table 15). However, to increase output from about 12 million to 13.6 million cubic feet would require nearly a threefold increase in spending.

By adding management on Special Land, supplies of wood could be increased, but not very efficiently. Such inefficiency is indicated by the flatness of the curve, which reflects the high marginal cost in relation to marginal output. If Marginal Land became available because of improved technology, additional timber output could be generated.

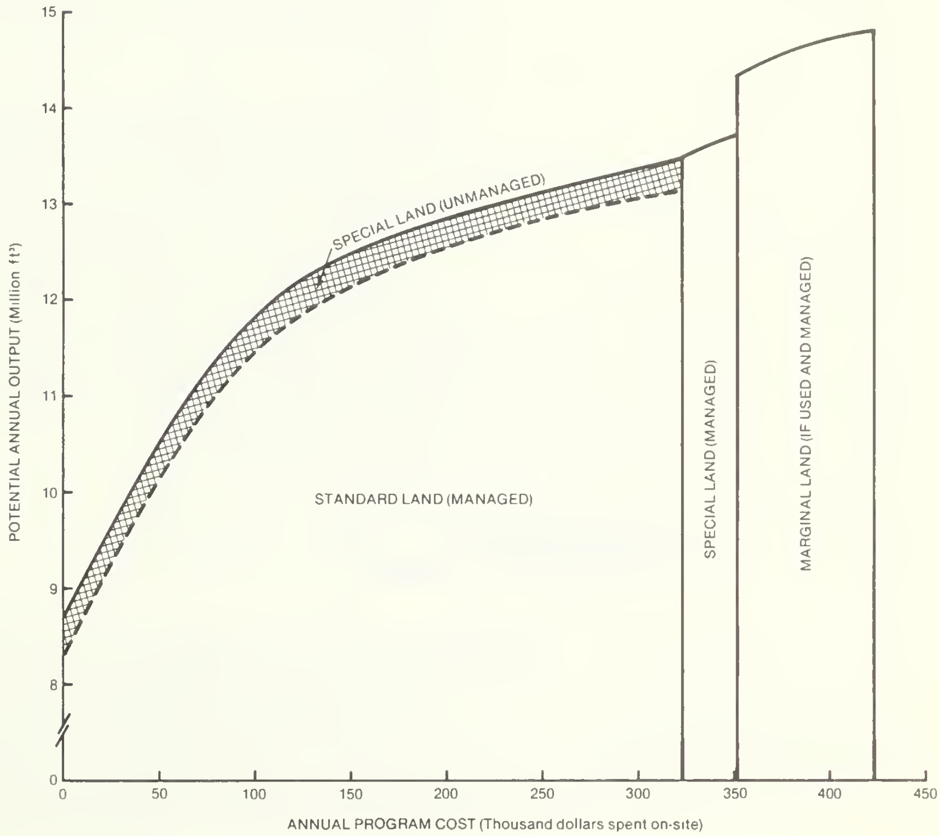
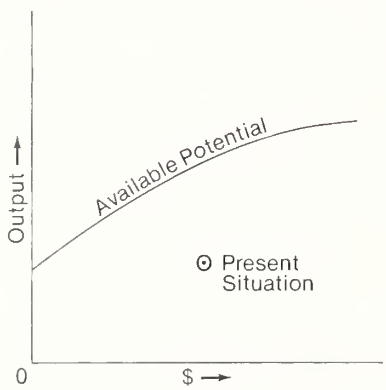



*Figure 1.--Potential output curve.*

# ASSESSING THE PRESENT SITUATION

## Monitoring Present Program and Output




The present situation in relation to the potential should be explainable...

■ A COMPARISON. Two kinds of information are generated from basic timber inventory data: (1) an estimate of the sustainable allowable cut (both short and long run), and (2) a plan of management that describes how the short-run allowable cut is to be achieved (usually for a 10-year planning period).

As a beginning point for assessment of the current situation, the available potential output curve has some utility as a monitoring device. If the working circle were in a fully regulated condition, average annual and current annual output and expenditures would be expected to be close to those defined by the curve, given the present harvesting policy of nondeclining even flow.

For a working circle being brought into a regulated condition, average annual or current annual output and expenditures could vary widely from the curve, depending on the nature and character of the existing timber resource and the harvesting schedule in force. For any given year, output or expenditures could be high or low in relation to each other for any of several reasons.

but not necessarily judged.

A high output-low expenditure situation might indicate a harvest fluctuation around some lower average sustained-yield figure that compensates for a lesser harvest in a prior year. A low output-high expenditure situation could represent some "catchup" management effort made possible by increased K-V deposits from a prior year or appropriated P&M money, or both. The point is, however, that by comparing the estimated potential output and associated management costs with the current levels of output and expenditures, the manager has the opportunity to monitor the overall progress of his management program.

## Interpreting Specific Situations

A resource profile can show the manager what he faces.

■ LOOKING AT CLUES. The timber inventory provides data from which a resource profile can be developed. Such information identifies specific management situations or resource conditions that are relatively homogenous in terms of required management input and that must be dealt with in future management to meet timber production goals. In addition, this

information helps establish the sustainable harvest over the next planning period and is the basis for estimating the probable output over the next rotation. The task is to reduce the mass of data to some form that makes interpretation of the various resource situations simpler.

Effective use of available land is a key factor in achieving output goals.

■ LAND-USE EFFECTIVENESS. A major factor in timber output is the effectiveness with which available land is used. A look at the stocking situation by land-productivity class provides a starting point for evaluation (table 5).

Sawtimber stands dominate, and the area classified as "nonstocked" does not appear to be excessively large. All nonstocked land is on the poorest sites. These are outwardly good signs; however, a deeper look into the real nature of the stands is required to pass judgment on the effectiveness with which the land is being utilized.

Table.5--*Ponderosa pine and Douglas-fir commercial forest land area by stand size and productivity class*

| Productivity class ($ft^3$/acre/yr) | Sawtimber | Poletimber | Seedling sapling | Nonstocked | Total |
|---|---|---|---|---|---|
| | | | *Acres* | | |
| 20-35 | 293,048 | 23,875 | 3,549 | 17,879 | 338,351 |
| 36-50 | 66,749 | 4,751 | 0 | 0 | 71,500 |
| 50+ | 23,837 | 0 | 0 | 0 | 23,837 |
| Total | 383,634 | 28,626 | 3,549 | 17,879 | 433,688 |

Nonstocked...

understocked...

The data for Douglas-fir and ponderosa pine land in table 5 are based on the classification of the sample field plot as to whether or not it is stocked and, if so, the size of trees present. Stand-size classification alone can be misleading because of the way stand sizes are defined. Sawtimber stands need to be only 16.7 percent stocked with growing stock trees and only half the total stocking must be in sawtimber and pole trees. So a stand classified as sawtimber (based on crown occupancy) could have large numbers of smaller diameter trees in it.

"misstocked"...

or overstocked?

Moreover, even though enough trees may be present to classify the area as stocked with trees, there are the questions of adequacy and desirability of the stocking. The stocking percent at each of the 10 sample points within the field location provides good additional information about the utilization of commercial forest land for timber production (table 6).

Table 6.--*Commercial forest land by stocking category and productivity class*[1]

| Productivity class (ft$^3$/acre/yr) | Commercial forest land stocked with trees: Live-tree area | Growing-stock area | Cull-tree area | Nonstocked area | Total area[2] |
|---|---|---|---|---|---|
| | *Acres* | | | | |
| 20-35 | 276,870 | 221,403 | 55,467 | 64,987 | 341,857 |
| 36-50 | 68,085 | 65,445 | 2,640 | 3,415 | 71,500 |
| 50+ | 26,712 | 26,154 | 558 | 551 | 27,263 |
| Total | 371,667 | 313,002 | 58,665 | 68,953 | 440,620 |

[1]Area figures in this table and indexes derived from them are for the entire working circle, in contrast to table 5 which includes only the ponderosa pine and Douglas-fir lands. These acreage differences are not significant in terms of illustrating the use of such data.

[2]Total area equals the sum of nonstocked areas and areas stocked with growing-stock and cull trees.

$$RI = \frac{\text{Area stocked with live trees}}{\text{Total area}}$$

△ REGENERATION SITUATION. The degree to which the available commercial forest land is stocked and the kind and nature of the trees present is, to a large extent, a reflection of past regeneration success. One indication of the existence and size of a possible regeneration problem is the relation of the area stocked with live trees to the area available for growing trees. A Regeneration Index can be computed from table 6 data,

$$RI = \frac{371,667}{440,620} = 0.84$$ and for low-productivity land, RI = 0.81.

The computed values of the various indexes used in this analysis are presented in table 7, along with definitions.

Table 7.--*Summary of indexes*[1] *used to evaluate the timber resource*

| Land productivity class | Regeneration Index | Land Effectiveness Index | Management Index 1 | Management Index 2 | Mortality Index | Tree Development Index |
|---|---|---|---|---|---|---|
| 20-35 | 0.81 | 0.65 | 0.46 | 0.56 | 0.82 | Not computed |
| 36-50 | .95 | .92 | .62 | .74 | .84 | Not computed |
| 50+ | .98 | .96 | .40 | .60 | .67 | 0.83 |
| Total | .84 | .71 | .48 | .60 | .81 | -- |

[1]Regeneration Index = area stocked with live trees ÷ total area
Land Effectiveness Index = adjusted growing stock area ÷ total area
Management Index 1 = net growth per acre ÷ potential growth per acre
Management Index 2 = gross growth per acre ÷ potential growth per acre
Mortality Index = net annual growth ÷ gross annual growth
Tree Development Index = basal area of average tree ÷ average tree basal area expected

Over the entire working circle, 64,987 acres of low-productivity land are considered to be nonstocked.

The 17,879 acres on ponderosa pine and Douglas-fir land are those without enough trees to be considered stocked and probably are mostly areas recently cutover in the process of reforestation. The 64,987 acres include the 17,879 nonstocked acres, the remainder (47,108 acres) is made up of other nonstocked areas and unoccupied space in lightly stocked stands, based on the stocking percent at each of the 10 sample points of the field locations.

There may be no quick remedy apparent for a stocking problem, but

One can argue that it is unreasonable to consider planting all the openings with seedlings and, therefore, pointless to sum up the thousands of openings and classify them as nonstocked.

the situation is exposed for future planning.

Also, adjacent trees may be utilizing some apparently unused open areas. Such an argument misses the significance of such openings in terms of effective use of available land for growing wood.

Effective use of commercial forest land for timber production would seem to indicate reasonably prompt and adequate regeneration and a high proportion of growing-stock trees. From table 6, a Land Effectiveness Index (LEI) can be computed as the proportion of available commercial forest land currently stocked with growing-stock trees.

$$LEI = \frac{\text{Area occupied by growing-stock trees}}{\text{Total area available}}$$

In this case, only 313,000 acres of the 440,620 available are classed as being occupied with growing-stock trees (LEI = 0.71), that is, those trees that would be featured in management. For low-productivity land the LEI is only 0.65 (table 7).

Judgment on the magnitude of the LEI must be tempered by...

Although the Regeneration Index for low-productivity land was 0.81, the LEI for those same acres is only 0.65, an indication that many nongrowing-stock trees occupy the commercial forest land area. Some 55,467 acres (16 percent) of low-site land are occupied by cull trees, which contribute about as much to the timber production as the bare areas they preclude. Again, this does not mean cull stands, but rather nonmerchantable trees (most of which are probably a nonmerchantable species such as juniper) scattered through an otherwise merchantable stand. The area occupied by cull trees and the unused area in lightly stocked stands combine to reduce the effective area contributing to annual output. On the working circle inventoried, data show a total of 127,618 acres are low producers. That area comprises nearly 29 percent of the total commercial forest land and represents a potential production loss of up to 4.3 million cubic feet annually (table 8) on ponderosa pine and Douglas-fir lands.

Table 8.--*Average productivity, stockable area not being used by growing-stock trees, and productivity lost*

| Productivity class | Average productivity | Unutilized area | Cumulative total | Production lost | Cumulative total |
|---|---|---|---|---|---|
| | - - - - $Ft^3/a/yr$ - - - - | - - - - *Acres* - - - - | | - - - - $Ft^3/yr$ - - - - | |
| 20-35 | 33 | 120,454 | 120,454 | 3,974,982 | 3,974,982 |
| 36-50 | 48 | 6,055 | 126,509 | 290,640 | 4,265,622 |
| 50+ | 65 | 1,109 | 127,618 | 72,085 | 4,337,707 |

consideration of other use goals for the forest area.

Whether any remedy is possible or desirable at present is another question. If the nonstocked area is high-producing livestock range or wildlife habitat that fits into the overall scheme of the management objectives, the situation is not a problem. Rather, it is a measure of the relative values of grazing opportunity, wildlife habitat, and timber.

If on the other hand the timber values outweigh other uses, the situation should be acted upon as existing stands are cut and regenerated in the future. It must be considered now, however, in estimating short-run timber supplies and planning for the future management of the resource.

□ STAND DENSITY AND STRUCTURE. The need or opportunity to improve stand structure to increase output can be assessed by comparing actual average density and tree-size distribution with the density and size distribution represented by a fully regulated forest from which potential yield may be captured.

Stand density and structure of the average stand in a fully regulated forest can serve as a benchmark for determining management needs.

An approximation of average basal area per acre in growing-stock trees by diameter class can be developed for the entire commercial forest land area from total numbers of trees by diameter class and area by productivity class (appendix table 17).

The desired, or target, stand structure can be estimated from known periodic growth rates for a given site quality and the growing-stock level sought for the residual stand after thinning.

The reason this comparison can be made and has meaning is fairly simple. In dealing with an entire forest or all forest land having a given productivity potential, "average" stocking would approach that of a selection forest. This would be true whether you have even- or uneven-aged management. The cutting cycle, or period, would set the range in actual stocking

and the average stand described would represent the midpoint of the range. This is simply to take into account the fact that the trees are growing.

As an example, research has shown that on high-site land in the southwest, ponderosa pine managed at growing stock level 100 on a 20-year thinning cycle would grow at a rate of about 0.11 inch per year. The residual 100 square feet of basal area after thinning would grow to almost 170 square feet during that 20-year period. The average for a collection of these stands whose stage of development would coincide with each year in the cutting cycle would be about 135 square feet of basal area per acre (fig. 2), representing the basal area about 10 years after thinning.

The current actual average for high-site land on the working circle inventoried is only 87 square feet per acre (fig. 2). It is apparent that, in this case, the problem is not one to be solved by an increased thinning effort. While thinning opportunities surely exist in individual stands and could change the diameter distribution to something more closely resembling the desired stand structure (shape of target curve), the problem of stand density will remain. Stocking deficiency can only be solved over a rather long period of time.

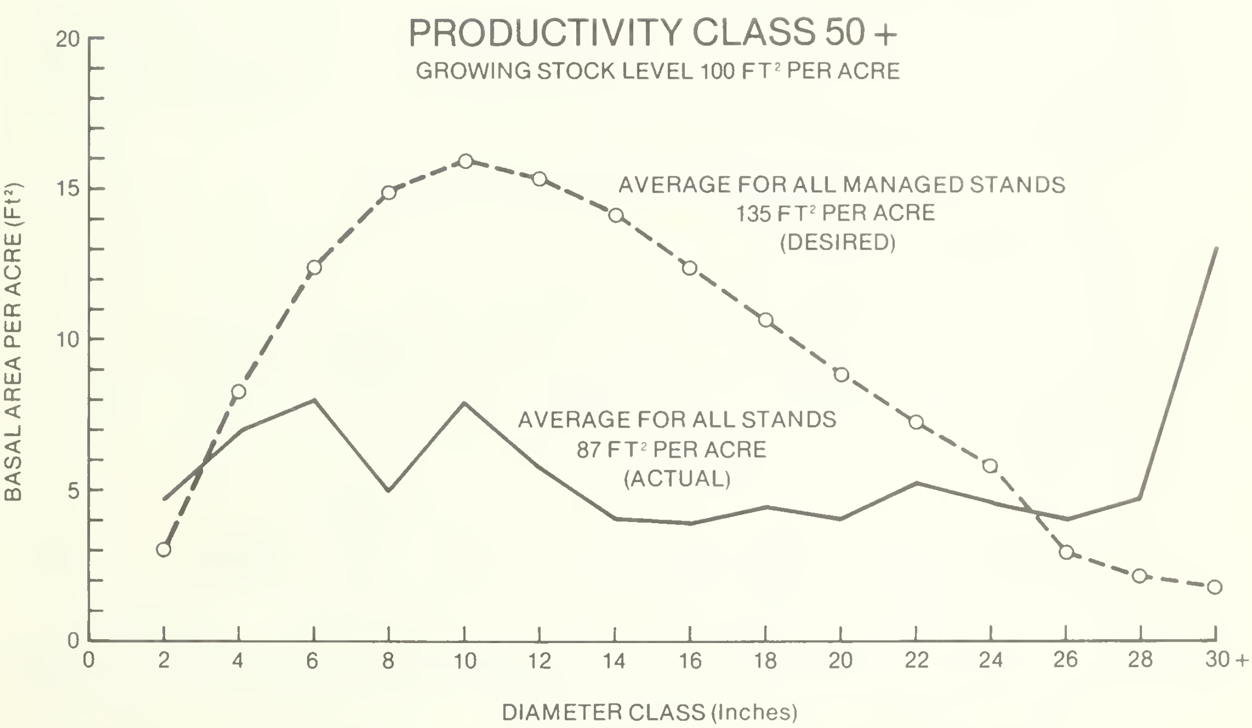



*Figure 2.--Actual and desired average basal area stocking per acre by diameter class. Growing stock level: basal area in square feet per acre that will remain after thinning when d.b.h. is ≥10.0 inches.*

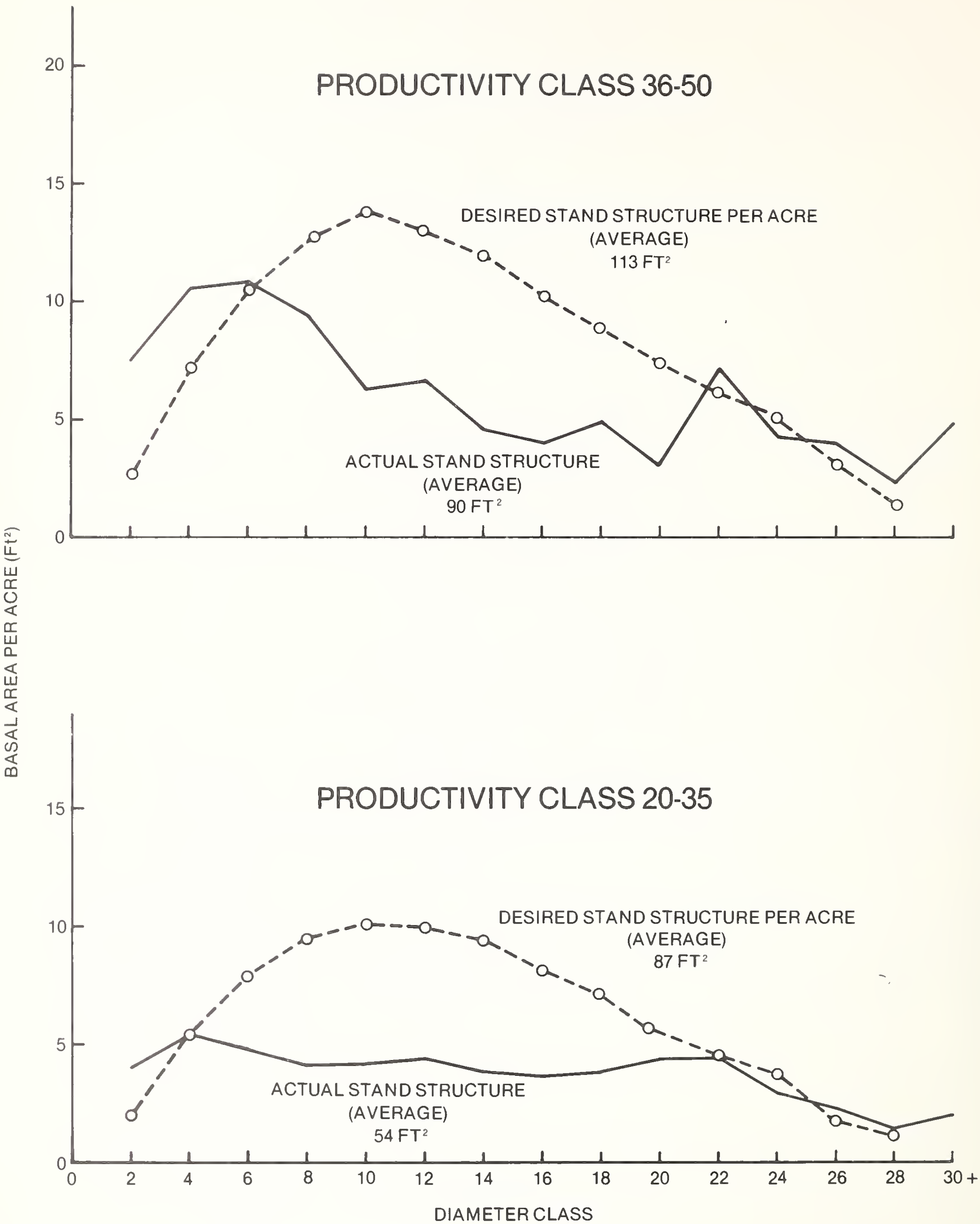



*Figure 3.--Actual and desired basal area stocking per acre by diameter class.*

An accelerated thinning program could help a stand structure problem but not a stand density problem.

Is this a problem peculiar to only the high-site land? Not according to similar data for medium and low sites (fig. 3), even though productivity class 36 to 50 land seems to be in a better position than the lowest site lands. These comparisons support to a great degree some observations made about the adequacy of stocking indicated by the Regeneration and Land Effectiveness Indexes.

In figures 2 and 3, the stand structure situation is all but obscured by the low stocking level. Under a managed condition, as indicated by the desired structure of the 135 square feet basal area per acre curve, the basal area in trees less than 10 inches d.b.h. should be about 40 percent of the basal area in trees 10 inches d.b.h. and larger, or approximately 30 percent of the total basal area. This is true regardless of growing-stock level maintained. In this case, stands on low- and medium-productivity lands have unduly large proportions of basal area in trees less than 10 inches in diameter (table 9). It appears to be only coincidental that on high-site land basal area is properly distributed between the two size-class groups. The high-basal area in trees 30 inches d.b.h. and larger evidently offsets the low basal area per acre in trees 8 inches in diameter.

Stand structure imbalances also indicate imbalances in age classes that could affect future available output.

In situations like this, the manager must consider some strategies for manipulating the resource to achieve his management goals, or else reduce the target density with the idea of achieving the structure and building up the density during the conversion period. However, the acceptance of a lower target density seems to avoid the problem rather than to come to grips with it. A more detailed examination of the resource

Table 9.--*Comparison of stand structure under full management and present stand structure by productivity class*

| Productivity class ft³/acre/yr | MANAGED STANDS: Basal area per acre: d.b.h.<10 | d.b.h.≥10 | Total | Ratio | % of total | ACTUAL STANDS: Basal area per acre: d.b.h.<10 | d.b.h.≥10 | Total | Ratio | % of total |
|---|---|---|---|---|---|---|---|---|---|---|
| | - - - - - *Ft²* | - - - - - | | - -*Percent*- | - | - - - - - *Ft²* | - - - - - | | - -*Percent*- | - |
| 20-35 | 25.0 | 61.8 | 86.8 | 0.40 | 0.29 | 18.3 | 35.3 | 53.6 | 0.52 | 0.34 |
| 36-50 | 32.8 | 80.6 | 113.4 | .41 | .29 | 38.0 | 52.3 | 90.3 | .72 | .42 |
| 50+ | [1] 38.5 | 96.8 | 135.3 | .40 | .28 | 24.9 | 62.1 | 87.0 | .40 | .29 |

[1] All data in table 9 can be developed from appendix table 17. In figure 2, the basal areas per acre by diameter class are:

d.b.h. 2 inches = 3.0 $ft^2$
d.b.h. 4 inches = 8.2 $ft^2$
d.b.h. 6 inches = 12.3 $ft^2$
d.b.h. 8 inches = 15.0 $ft^2$
Total = 38.5 $ft^2$

to determine the extent of variations in stand densities by productivity class would be useful. It might indicate more clearly the nature and size of the job required to increase, by the end of the conversion period, annual output to a level close to the realistic available potential estimated for the commercial forest land.

A generally understocked forest can have overstocked stands. Tree development reflects the existence of thinning opportunities.

TREE DEVELOPMENT. Actual tree development in relation to potential development under the various stand density and stand structure targets is another indicator of management need in terms of thinning. A Tree Development Index (TDI) compares the actual average tree basal area (BA) and the average tree basal area expected, considering the stand density maintained.

$$\text{TDI} = \frac{\text{BA of average tree (actual)}}{\text{BA of average tree (expected)}}$$

From the inventory data, the diameter of the tree of average basal area can be determined along with stand age. Then, for any given stand age, a diameter can be read. If this is done for each productivity class, a picture of tree development for the existing stand is produced. If diameter growth for specific target stand densities is to be predicted through growth-response studies or calculated from managed-stand volume and yield studies, a Tree Development Index can be calculated.

Gilbert Schubert, principal silviculturist at the Forestry Sciences Laboratory in Flagstaff, Arizona, developed average stand diameters for managed southwest ponderosa pine stands on productivity class 50+ lands and for growing stock levels 30 through 100. Growing-stock level 100 would have an average basal area of 135 square feet on 425 trees:

| Growing stock level | Average Stand Basal area ft$^2$ | Average Stand d.b.h. |
|---|---|---|
| 30 | 0.3216 | 7.7 |
| 50 | .3154 | 7.6 |
| 60 | .3152 | 7.6 |
| 70 | .3121 | 7.6 |
| 80 | .3114 | 7.6 |
| 100 | .3181 | 7.6 |
| Average | 0.3156 | 7.6 |

These data represent the average for a fully regulated forest. There are 10,910,000 trees on the 27,263 acres of high-productivity lands, or 400 trees per acre. Actual average basal area per acre is 87 square feet, or 0.2175 square feet per tree. Comparing the expected average diameter of 7.6 (average tree basal area of 0.3181 square feet) with the average

actual tree diameter of 6.3 (average tree basal area of 0.2175 square feet) yields a Tree Development Index of 0.83. This indicates some thinning opportunities on high-site lands exist, even though the overall problem of understocking is obvious as indicated in figure 2.

□ VOLUME, GROWTH, AND MORTALITY. Volume and growth summaries by land-productivity class (tables 10 and 11) are

Table 10.--*Volume and growth by productivity class*

| Category | PRODUCTIVITY CLASS 20-35 | 36-50 | 50+ | Total |
|---|---|---|---|---|
| | *Ft³* | | | |
| Net growing stock volume in: | | | | |
| Desirable trees | 104,189,671 | 31,553,321 | 19,572,047 | |
| Acceptable trees | 216,419,870 | 78,927,300 | 42,495,384 | |
| Total | 320,609,541 | 110,480,621 | 62,067,431 | 493,157,593 |
| Volume in: | | | | |
| Rough trees | 5,495,694 | 2,513,811 | 1,035,080 | |
| Rotten trees | 345,837 | 157,142 | 102,738 | |
| Total | 5,841,531 | 2,670,953 | 1,137,818 | 9,650,302 |
| Total volume | 326,451,072 | 113,151,574 | 63,205,249 | 502,807,895 |
| Net growth (per year): | | | | |
| Softwoods | 5,226,255 | 2,113,557 | 595,640 | 7,935,452 |
| Hardwoods | -38,376 | 2,221 | 107,314 | 71,159 |
| Total | 5,187,879 | 2,115,778 | 702,954 | 8,006,611 |
| Mortality (per year): | | | | |
| Softwoods | 1,065,751 | 411,593 | 347,348 | 1,824,692 |
| Hardwoods | 95,653 | 0 | 6,013 | 101,666 |
| Total | 1,161,404 | 411,593 | 353,361 | 1,926,358 |
| Gross growth (per year): | | | | |
| Softwoods | 6,292,006 | 2,525,150 | 942,988 | 9,760,144 |
| Hardwoods | 57,277 | 2,221 | 113,327 | 172,825 |
| Total | 6,349,283 | 2,527,371 | 1,056,315 | 9,932,969 |
| Potential growth for softwoods | 33 | 48 | 65 | |
| Total | 11,281,281 | 3,432,000 | 1,772,095 | 16,485,376 |

Table 11.--*Per acre volume, growth, and mortality for the stocked area and the area stocked with growing-stock trees by land-productivity class*

| Category | Land-productivity class 20-35 | 36-50 | 50+ | Total |
|---|---|---|---|---|
| | STOCKED AREA (ACRES) | | | |
| | 341,857 | 71,500 | 27,263 | 440,620 |
| | - - - - - - *Ft³/acre* - - - - - - | | | |
| Growing-stock volume | 938 | 1,545 | 2,277 | |
| Gross growth per year | 18.6 | 35.3 | 38.7 | |
| Mortality per year | 3.4 | 5.8 | 13.0 | |
| Net growth per year | 15.2 | 29.6 | 25.8 | |
| | AREA STOCKED WITH GROWING-STOCK TREES (ACRES) | | | |
| | 221,403 | 65,445 | 26,154 | 313,002 |
| | - - - - - - *Ft³/acre* - - - - - - | | | |
| Growing-stock volume | 1,448 | 1,688 | 2,373 | |
| Gross growth per year | 28.7 | 38.6 | 40.4 | |
| Mortality per year | 5.2 | 6.3 | 13.5 | |
| Net growth per year | 23.4 | 32.3 | 26.9 | |

Past management generated present growth. The effectiveness of such management should be examined.

a major source of insight into the current status and performance of the timber resource. Because recent performance is largely the result of past management, such data provide a base for judging the adequacy of the present timber-growing program as well as some clues for future management direction and emphasis.

Current annual production is actually a measure of periodic annual increment, but production potential is measured as mean annual increment. Obviously, these two measures of growth are not comparable except for fully regulated forest areas. While such comparisons have no validity for judging the performance of an individual stand, they do have meaning for a general overview of a working circle.

Management I =

$$\frac{\text{Net growth per acre}}{\text{Potential growth per acre}}$$

△ MANAGEMENT EFFECTIVENESS. The effect of past management can be partially gaged by a Management Index that compares potential per acre annual growth with recent actual growth (table 7). This index is computed by using net annual growth and potential growth for softwoods from table 10.

$$\text{Management I} = \frac{7,935,452}{16,485,376} = 0.48$$ for the entire working circle, with the performance of high-site land even lower (0.40).

Mortality I, =

$$\frac{\text{Total net annual growth}}{\text{Total gross annual growth}}$$

Mortality is the first factor that comes to mind in the way of explanation. A Mortality Index can be used to help explain the Management Index value.

Mortality does not necessarily deserve all the blame for low net growth rates.

This computes to 0.81 for all commercial forest land on the working circle inventoried (table 7). Note, however, that a much higher Mortality Index is indicated for high-site land. This can be attributed to a wildfire that prior to the inventory, burned over nearly 20,000 acres, mostly better quality land occupied by ponderosa pine. But, does mortality alone account for the difference between potential and actual growth? A clue can be found by another Management Index that relates gross growth to potential.

(Management $I_2$)

$$\frac{\text{Total gross growth per acre}}{\text{Total potential growth per acre}}$$

This index value for the working circle inventoried averages 0.60 for all commercial forest land (table 7), a figure too low to justify attributing the entire difference between actual and potential growth to mortality that only claimed 19 percent of gross growth. In the previous section, it was noted that only 71 percent of the area available actually was stocked with growing stock. That would account for part of the growth gap. Also, stand density appeared to be significantly deficient on all commercial forest land.

The output possibilities and the present situation can be shown and examined graphically.

In table 11, volume and growth on the working circle inventoried have been summarized by land-productivity class for the stocked area and for the area stocked with growing-stock trees. Some interesting comparisons can be made between current and potential output.

The relation of current growth to potential yields can also be shown graphically (fig. 4). Beginning with the most productive land, volumes and acres are cumulatively summed, adding in less and less productive land. The volume figures are the per acre values multiplied by the number of acres; the data are from table 11.

The disquieting feature of this comparison is, of course, the big gap between present net growth and the future potential available yield. What are the opportunities for increasing output through more intensive management?

Present output in relation to expectations from increased management activities can be revealing.

In developing the potential output curve, four levels of management with their associated costs and expected output were considered. If the expected annual yields given for the four levels of management are applied to all the area in each productivity class, a graphic display similar to figure 4 can be generated (fig. 5). Again, cumulative totals are used, but only Standard Land has been used to illustrate the method.

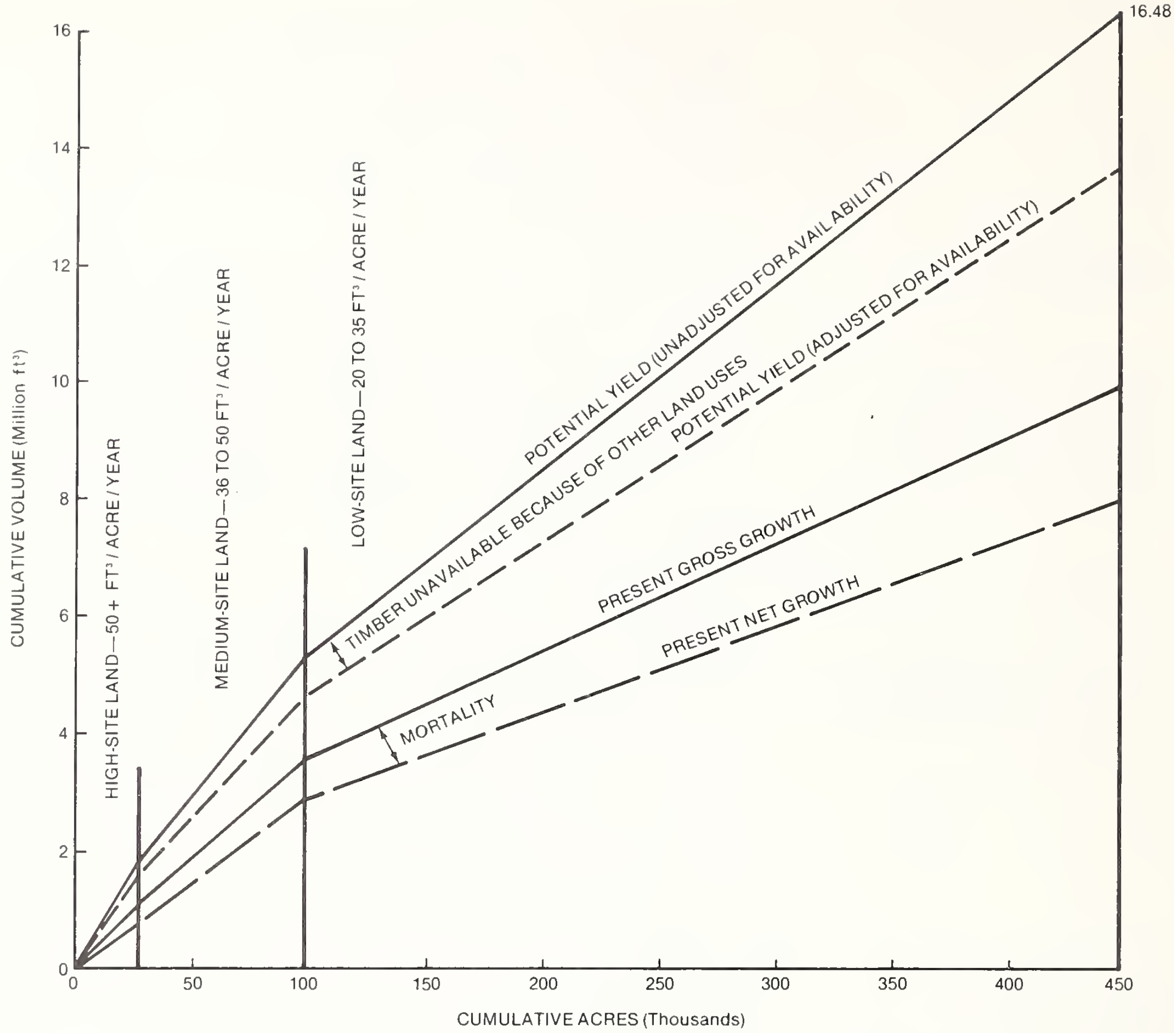



*Figure 4.--Present growth and potential yield per year.*

One ridiculous conclusion that might be drawn from the graph is that the annual yield could be increased by nearly 2 million cubic feet merely by stopping all management.

Opportunities for increasing output can be shown from this kind of analysis...

The expected levels of output for each management level are for a fully regulated forest and predicated on the assumption that all the available land would be adequately stocked eventually, even at Level 1 (no management). The important point of figure 4 is the extent of the opportunity to increase timber supplies by increasing net growth using whatever means may be most appropriate. This possibility should come as no surprise considering some of the "clues" developed in previous sections:

1. A sizable area of land is nonstocked, understocked, or occupied by cull trees.
2. Average stand density is considerably less than desired.

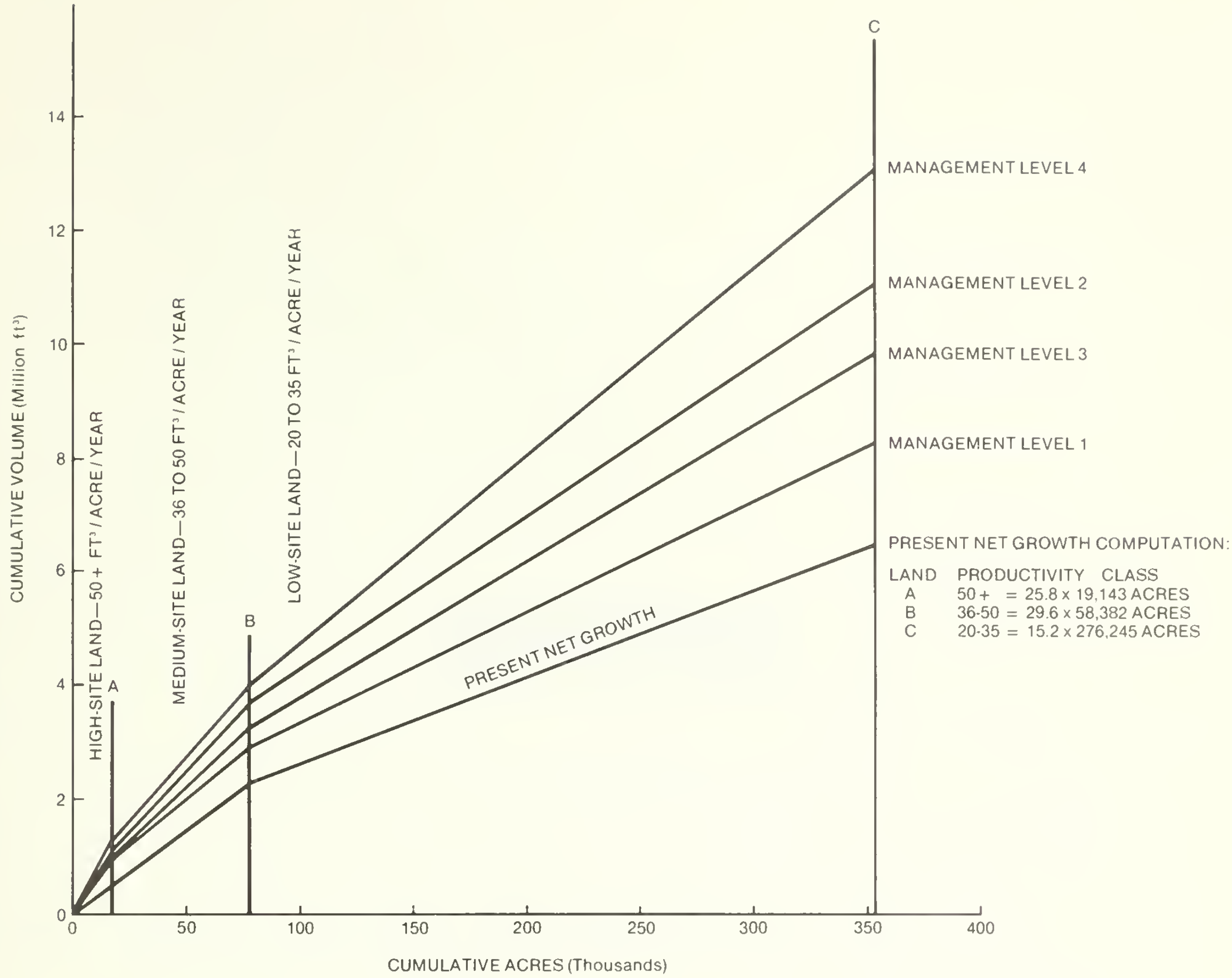



*Figure 5.--Present growth and expected yields under four levels of Management, Standard Land.*

but the manager must decide what must be done and consider the costs involved when planning his future approach for accomplishing his goals.

3. Stand structure is in need of improvement from the standpoint of timber production.
4. There appear to be mortality problems.

According to figure 5, given adequate stocking, the present actual net growth on Standard Land could be achieved by intensively managing only 150,000 acres. However, still unanswered is question of what should be done and how it should be done on the commercial forest land involved.

Further disaggregation of the commercial forest land into specific situation categories, such as sparse sawtimber stands, overstocked pole timber stands, or partially regenerated cutover areas, will identify real management opportunities. These opportunities can then be evaluated on the basis of treatment costs and expected responses or value returns to develop rational management strategies that are economically efficient in realizing production goals.

# APPENDIX

Table 12.--*Basic cost and yield information and work sheet*

STANDARD LAND

| Avail. class | Land prod. class | Ave. | Mgt. level | Regen. period | Growing period | Rotation | Yield expected: Per acre total | Yield expected: Per acre per year | Management costs/acre: Regen. | Management costs/acre: P.C. thin | Management costs/acre: Other | Management costs/acre: Total | Production costs: Per unit yield (12) ÷ (7) | Production costs: Annual per acre (12) ÷ (6) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) |
| | *Ft*$^3$*/a/yr* | | | *Years* | | | *Ft*$^3$ | | *$* | | | | | |
| I | 20-35 | 33 | 1 | 25 | 95 | 120 | 2,400 | 20.0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | A[1] | | 2 | 25 | 95 | 120 | 3,215 | 26.8 | 0 | 15 | 10 | 25 | 0.008 | 0.21 |
| | (Acres) | | 3 | 5 | 115 | 120 | 2,904 | 24.2 | 25 | 0 | 0 | 25 | .009 | .21 |
| | 276,245 | | 4 | 3 | 117 | 120 | 3,960 | 33.0 | 90 | 15 | 10 | 115 | .029 | .96 |
| | 36-50 | 48 | 1 | 15 | 105 | 120 | 4,250 | 35.4 | 0 | 0 | 0 | 0 | 0 | 0 |
| | B | | 2 | 15 | 105 | 120 | 5,169 | 43.1 | 0 | 20 | 15 | 35 | .007 | .29 |
| | (Acres) | | 3 | 5 | 115 | 120 | 4,655 | 38.8 | 13 | 0 | 0 | 13 | .003 | .11 |
| | 58,382 | | 4 | 3 | 117 | 120 | 5,760 | 48.0 | 63 | 20 | 15 | 98 | .017 | .82 |
| | 50+ | 65 | 1 | 10 | 110 | 120 | 5,790 | 48.2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | C | | 2 | 10 | 110 | 120 | 7,334 | 61.1 | 0 | 25 | 20 | 45 | .006 | .38 |
| | (Acres) | | 3 | 5 | 115 | 120 | 6,054 | 50.4 | 7 | 0 | 0 | 7 | .001 | .06 |
| | 19,143 | | 4 | 3 | 117 | 120 | 7,800 | 65.0 | 17 | 25 | 20 | 62 | .008 | .52 |

Total area (Acres)
353,770

[1] See table 3, footnote 2.

Table 13.--*Basic cost and yield information and work sheet*

SPECIAL LAND

| Avail. class (1) | Land prod. class (2) | Ave. | Mgt. level (3) | Regen. period (4) | Growing period (5) | Rotation (6) | Yield expected: Per acre total (7) | Yield expected: Per acre per year (8) | Management costs/acre: Regen. (9) | Management costs/acre: P.C.thin (10) | Management costs/acre: Other (11) | Management costs/acre: Total (12) | Production costs: Per unit yield (13) | Production costs: Annual per acre (14) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Ft³/a/yr* | | *Years* | | | *Ft³* | | *$* | | | | | |
| I | 20-35 | 33 | 1 | 25 | 95 | 120 | 2,400 | 20.0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | 2 | 25 | 95 | 120 | 3,215 | 26.8 | 0 | 15 | 10 | 25 | 0.008 | 0.21 |
| | (Acres) | | 3 | 5 | 115 | 120 | 2,904 | 24.2 | 25 | 0 | 0 | 25 | .009 | .21 |
| | 1,088 | | 4 | 3 | 117 | 120 | 3,960 | 33.0 | 90 | 15 | 10 | 115 | .029 | .96 |
| | 36-50 | 48 | 1 | 15 | 105 | 120 | 4,250 | 35.4 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | 2 | 15 | 105 | 120 | 5,169 | 43.1 | 0 | 20 | 15 | 35 | .007 | .29 |
| | (Acres) | | 3 | 5 | 115 | 120 | 4,655 | 38.8 | 13 | 0 | 0 | 13 | .003 | .11 |
| | 272 | | 4 | 3 | 117 | 120 | 5,760 | 48.0 | 63 | 20 | 15 | 98 | .017 | .82 |
| | 50+ | 65 | 1 | 10 | 110 | 120 | 5,790 | 48.2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | 2 | 10 | 110 | 120 | 7,334 | 61.1 | 0 | 25 | 20 | 45 | .006 | .38 |
| | (Acres) | | 3 | 5 | 115 | 120 | 6,054 | 50.4 | 7 | 0 | 0 | 7 | .001 | .06 |
| | 14 | | 4 | 3 | 117 | 120 | 7,800 | 65.0 | 17 | 25 | 20 | 62 | .008 | .52 |

Total Area (Acres)
1,374

*(con.)*

Table 13.--(con.)

SPECIAL LAND

| Avail. class (1) | Land prod. class (2) | Ave. | Mgt. level (3) | Regen. period (4) | Growing period (5) | Rotation (6) | Yield expected: Per acre total (7) | Yield expected: Per acre per year (8) | Management costs/acre: Regen. (9) | Management costs/acre: P.C.thin (10) | Management costs/acre: Other (11) | Management costs/acre: Total (12) | Production costs: Per unit yield (13) | Production costs: Annual per acre (14) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $Ft^3/a/yr$ | Years | | | | $Ft^3$ | | $ | | | | | |
| II | 20-35 | 33 | 1 | 25 | 95 | 120 | 2,160 | 18.0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | 2 | 25 | 95 | 120 | 2,894 | 24.1 | 0 | 15 | 45 | 60 | 0.021 | 0.50 |
| | (Acres) | | 3 | 5 | 115 | 120 | 2,615 | 21.8 | 25 | 0 | 0 | 25 | .010 | .21 |
| | 10,228 | | 4 | 3 | 117 | 120 | 3,560 | 29.7 | 90 | 15 | 45 | 150 | .042 | 1.25 |
| | 36-50 | 48 | 1 | 15 | 105 | 120 | 3,825 | 31.9 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | 2 | 15 | 105 | 120 | 4,652 | 38.8 | 0 | 20 | 50 | 70 | .015 | .58 |
| | (Acres) | | 3 | 5 | 115 | 120 | 4,189 | 34.9 | 13 | 0 | 0 | 13 | .003 | .11 |
| | 2,447 | | 4 | 3 | 117 | 120 | 5,184 | 43.2 | 63 | 20 | 50 | 133 | .026 | 1.11 |
| | 50+ | 65 | 1 | 10 | 110 | 120 | 5,211 | 43.4 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | 2 | 10 | 110 | 120 | 6,601 | 55.0 | 0 | 25 | 55 | 80 | .012 | .67 |
| | (Acres) | | 3 | 5 | 115 | 120 | 5,449 | 45.4 | 7 | 0 | 0 | 7 | .001 | .06 |
| | 459 | | 4 | 3 | 117 | 120 | 7,020 | 58.5 | 17 | 25 | 55 | 97 | .014 | .81 |

Total Area (Acres)
13,134

(con.)

Table 13.--(*con.*)

SPECIAL LAND

| Avail. class (1) | Land prod. class (2) | Ave. | Mgt. level (3) | Regen. period (4) | Growing period (5) | Rotation (6) | Yield expected: Per acre total (7) | Yield expected: Per acre per year (8) | Management costs/acre: Regen. (9) | P.C.thin (10) | Other (11) | Total (12) | Production costs: Per unit yield (13) | Annual per acre (14) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Ft³/a/yr* | | | *Years* | | | *Ft³* | | *$* | | | | | |
| 111 | 20-35 | 33 | 1 | 25 | 95 | 120 | 240 | 2.0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | 2 | 25 | 95 | 120 | 322 | 2.7 | 0 | 20 | 30 | 50 | 0.155 | 0.42 |
| | (Acres) | | 3 | 5 | 115 | 120 | 290 | 2.4 | 15 | 0 | 0 | 15 | .052 | .12 |
| | 15,564 | | 4 | 3 | 117 | 120 | 396 | 3.3 | 15 | 20 | 30 | 65 | .164 | .54 |
| | 36-50 | 48 | 1 | 15 | 105 | 120 | 425 | 3.5 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | 2 | 15 | 105 | 120 | 517 | 4.3 | 0 | 25 | 35 | 60 | .116 | .50 |
| | (Acres) | | 3 | 5 | 115 | 120 | 466 | 3.9 | 10 | 0 | 0 | 10 | .021 | .08 |
| | 3,095 | | 4 | 3 | 117 | 120 | 576 | 4.8 | 10 | 25 | 35 | 70 | .122 | .58 |
| | 50+ | 65 | 1 | 10 | 110 | 120 | 579 | 4.8 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | 2 | 10 | 110 | 120 | 733 | 6.1 | 0 | 30 | 40 | 70 | .095 | .58 |
| | (Acres) | | 3 | 5 | 115 | 120 | 605 | 5.0 | 5 | 0 | 0 | 5 | .008 | .04 |
| | 1,093 | | 4 | 3 | 117 | 120 | 780 | 6.5 | 5 | 30 | 40 | 75 | .096 | .62 |

Total area (Acres)
19,752

(*con.*)

Table 13.--*(con.)*

SPECIAL LAND

| Avail. class (1) | Land prod. class | Ave. (2) | Mgt. level (3) | Regen. period (4) | Growing period (5) | Rotation (6) | Yield expected: Per acre total (7) | Yield expected: Per acre per year (8) | Management costs/acre: Regen. (9) | Management costs/acre: P.C. thin (10) | Management costs/acre: Other (11) | Management costs/acre: Total (12) | Production costs: Per unit yield (13) | Production costs: Annual per acre (14) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $Ft^3/a/yr$ | | *- - - - - - Years - - - -* | | | *- - - $Ft^3$ - - -* | | *- - - - - - - - - - - - - -* | *$ - - - - - - - - - - -* | | | | |
| IV | 20-35 | 33 | 1 | | | | | | | | | | | |
| | | | 2 | | | | | | | | | | | |
| | (Acres) | | 3 | | | | | | | | | | | |
| | 13,732 | | 4 | | | | | | | | | | | |
| | 36-50 | 48 | 1 | | | | | | | | | | | |
| | | | 2 | | | | | | | | | | | |
| | (Acres) | | 3 | | | | | | | | | | | |
| | 2,216 | | 4 | | | | | | | | | | | |
| | 50+ | 65 | 1 | | | | | | | | | | | |
| | | | 2 | | | | | | | | | | | |
| | (Acres) | | 3 | | | | | | | | | | | |
| | 836 | | 4 | | | | | | | | | | | |
| | Total area (Acres) 16,784 | | | | | | | | | | | | | |
| | Σ 51,044 | | | | | | | | | | | | | |

AZTEC LANDS UNAVAILABLE UNTIL 1999 (NO YIELD)

Table 14.--*Basic cost and yield information and work sheet*

MARGINAL LAND

| Avail. class (1) | Land prod. class | Ave. (2) | Mgt. level (3) | Regen. period (4) | Growing period (5) | Rotation (6) | Yield expected: Per acre total (7) | Yield expected: Per acre per year (8) | Management costs/acre: Regen. (9) | Management costs/acre: P.C. thin (10) | Management costs/acre: Other (11) | Management costs/acre: Total (12) | Production costs: Per unit yield (13) | Production costs: Annual per acre (14) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Ft³/a/yr* | | | *Years* | | | *Ft³* | | *$* | | | | | |
| I | 20-35 | 33 | 1 | 35 | 85 | 120 | 1,870 | 15.6 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | 2 | 35 | 85 | 120 | 2,877 | 24.0 | 0 | 75 | 75 | 150 | 0.052 | 1.25 |
| | (Acres) | | 3 | 5 | 115 | 120 | 2,530 | 21.1 | 80 | 0 | 0 | 80 | .032 | 0.67 |
| | 19,129 | | 4 | 3 | 117 | 120 | 3,960 | 33.0 | 150 | 75 | 75 | 300 | .076 | 2.50 |
| | 36-50 | 48 | 1 | 25 | 95 | 120 | 3,812 | 31.8 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | 2 | 25 | 95 | 120 | 4,677 | 39.0 | 0 | 80 | 80 | 160 | .034 | 1.33 |
| | (Acres) | | 3 | 5 | 115 | 120 | 4,615 | 38.5 | 60 | 0 | 0 | 60 | .013 | .50 |
| | 4,553 | | 4 | 3 | 117 | 120 | 5,760 | 48.0 | 130 | 80 | 80 | 290 | .050 | 2.42 |
| | 50+ | 65 | 1 | 10 | 110 | 120 | 5,790 | 48.2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | 2 | 10 | 110 | 120 | 7,333 | 61.1 | 0 | 85 | 85 | 170 | .023 | 1.42 |
| | (Acres) | | 3 | 5 | 115 | 120 | 6,054 | 50.4 | 40 | 0 | 0 | 40 | .007 | .33 |
| | 2,047 | | 4 | 3 | 117 | 120 | 7,800 | 65.0 | 110 | 85 | 85 | 280 | .036 | 2.33 |

Total Area (Acres)
25,729

(con.)

Table 14.--*(con.)*

MARGINAL LAND

| Avail. class (1) | Land prod. class (2) | Ave. | Mgt. level (3) | Regen. period (4) | Growing period (5) | Rotation (6) | Yield expected: Per acre total (7) | Yield expected: Per acre per year (8) | Management costs/acre: Regen. (9) | Management costs/acre: P.C.thin (10) | Management costs/acre: Other (11) | Management costs/acre: Total (12) | Production costs: Per unit yield (13) | Production costs: Annual per acre (14) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $Ft^3/a/yr$ | | *Years* | | | $Ft^3$ | | $ | | | | | |
| V | 20-35 | 33 | 1 | 40 | 80 | 120 | 820 | 6.8 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | 2 | 40 | 80 | 120 | 1,353 | 11.3 | 0 | 75 | 75 | 150 | 0.111 | 1.25 |
| | (Acres) | | 3 | 5 | 115 | 120 | 1,179 | 9.8 | 80 | 0 | 0 | 80 | .068 | .67 |
| | 2,365 | | 4 | 3 | 117 | 120 | 1,980 | 16.5 | 150 | 75 | 75 | 300 | .152 | 2.50 |
| | 36-50 | 48 | 1 | 35 | 85 | 120 | 1,675 | 14.0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | 2 | 35 | 85 | 120 | 2,092 | 17.4 | 0 | 80 | 80 | 160 | .076 | 1.33 |
| | (Acres) | | 3 | 5 | 115 | 120 | 2,266 | 18.9 | 60 | 0 | 0 | 60 | .026 | .50 |
| | 535 | | 4 | 3 | 117 | 120 | 2,880 | 24.0 | 130 | 80 | 80 | 290 | .101 | 2.42 |
| | 50+ | 65 | 1 | 15 | 105 | 120 | 2,800 | 23.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | 2 | 15 | 105 | 120 | 3,500 | 29.2 | 0 | 85 | 85 | 170 | .049 | 1.42 |
| | (Acres) | | 3 | 5 | 115 | 120 | 3,070 | 25.6 | 40 | 0 | 0 | 40 | .013 | .33 |
| | 245 | | 4 | 3 | 117 | 120 | 3,900 | 32.5 | 110 | 85 | 85 | 280 | .072 | 2.33 |

Total Area (Acres)
3,145
Σ
28,874

Table 15.--*Area and expected costs and yields by productivity class*

SPECIAL LAND

| Avail. class | Prod. class | Area (1) | Mgt. level (2) | Annual mgt. cost per acre (3) | Annual yield per acre (4) | Management cost per year (3) x (1) (5) | Yield expected per year (4) x (1) (6) | Cost per M cubic feet (5) ÷ (6) (7) | Rank (8) |
|---|---|---|---|---|---|---|---|---|---|
| | *$Ft^3$/a/yr* | *Acres* | | *$* | *$Ft^3$* | *$* | *$Ft^3$* | *$* | |
| I | 20-35 | 1,088 | 1 | 0 | 20.0 | 0 | 21,760 | 0 | 1 |
| | | | 2 | 0.21 | 26.8 | 228.48 | 29,158 | 7.84 | 6 |
| | A[1] | | 3 | .21 | 24.2 | 228.48 | 26,330 | 8.68 | 8 |
| | | | 4 | .96 | 33.0 | 1,044.48 | 35,904 | 29.09 | 10 |
| | 36-50 | 272 | 1 | 0 | 35.4 | 0 | 9,629 | 0 | 1 |
| | | | 2 | .29 | 43.1 | 78.88 | 11,723 | 6.73 | 5 |
| | B | | 3 | .11 | 38.8 | 29.92 | 10,554 | 2.83 | 3 |
| | | | 4 | .82 | 48.0 | 223.04 | 13,056 | 17.08 | 9 |
| | 50+ | 14 | 1 | 0 | 48.2 | 0 | 675 | 0 | 1 |
| | | | 2 | .38 | 61.6 | 5.32 | 862 | 6.17 | 4 |
| | C | | 3 | .06 | 50.4 | 0.84 | 706 | 1.19 | 2 |
| | | | 4 | .52 | 65.0 | 7.28 | 910 | 8.00 | 7 |
| | Total area | 1,374 | | | | | | | |

[1]See table 3, footnote 2.

*(con.)*

Table 15.--*(con.)*

SPECIAL LAND

| Avail. class | Prod. class | Area (1) | Mgt. level (2) | Annual mgt. cost per acre (3) | Annual yield per acre (4) | Management cost per year (3) x (1) (5) | Yield expected per year (4) x (1) (6) | Cost per M cubic feet (5) ÷ (6) (7) | Rank (8) |
|---|---|---|---|---|---|---|---|---|---|
| | *$Ft^3$/a/yr* | *Acres* | | *$* | *$Ft^3$* | *$* | *$Ft^3$* | *$* | |
| 11 | 20-35 | 10,228 | 1 | 0 | 18.0 | 0 | 184,104 | -- | 1 |
| | | | 2 | 0.50 | 24.1 | 5,114.00 | 246,495 | 20.75 | 8 |
| | A | | 3 | .21 | 21.8 | 2,147.88 | 222,970 | 9.63 | 4 |
| | | | 4 | 1.25 | 29.7 | 12,785.00 | 303,772 | 42.09 | 10 |
| | 30-50 | 2,447 | 1 | 0 | 31.9 | 0 | 78,059 | -- | 1 |
| | | | 2 | .58 | 38.8 | 1,419.26 | 94,944 | 14.95 | 7 |
| | B | | 3 | .11 | 34.9 | 269.17 | 85,400 | 3.15 | 3 |
| | | | 4 | 1.11 | 43.2 | 2,716.17 | 105,710 | 25.70 | 9 |
| | 50+ | 459 | 1 | 0 | 43.4 | 0 | 19,921 | -- | 1 |
| | | | 2 | .67 | 55.0 | 307.53 | 25,245 | 12.18 | 5 |
| | C | | 3 | .06 | 45.4 | 27.54 | 20,839 | 1.32 | 2 |
| | | | 4 | .81 | 58.5 | 371.79 | 26,852 | 13.85 | 6 |
| | Total area | 13,134 | | | | | | | |

*(con.)*

Table 15.--*(con.)*

SPECIAL LAND

| Avail. class | Prod. class | Area (1) | Mgt. level (2) | Annual mgt. cost per acre (3) | Annual yield per acre (4) | Management cost per year (3) x (1) (5) | Yield expected per year (4) x (1) (6) | Cost per M cubic feet (5) : (6) (7) | Rank (8) |
|---|---|---|---|---|---|---|---|---|---|
| | *Ft³/a/yr* | *Acres* | | *$* | *Ft³* | *$* | *Ft³* | *$* | |
| III | 20-35 | 15,564 | 1 | 0 | 2.0 | 0 | 31,128 | 0 | 1 |
| | | | 2 | 0.42 | 2.7 | 6,537 | 42,023 | 155.56 | 9 |
| | A | | 3 | .13 | 2.4 | 2,023 | 37,354 | 54.16 | 4 |
| | | | 4 | .54 | 3.3 | 8,405 | 51,361 | 163.65 | 10 |
| | 36-50 | 3,095 | 1 | 0 | 3.5 | 0 | 10,832 | 0 | 1 |
| | | | 2 | .50 | 4.3 | 1,548 | 13,308 | 116.32 | 7 |
| | B | | 3 | .08 | 3.9 | 248 | 12,070 | 20.55 | 3 |
| | | | 4 | .58 | 4.8 | 1,795 | 14,856 | 120.83 | 8 |
| | 50+ | 1,093 | 1 | 0 | 4.8 | 0 | 5,246 | 0 | 1 |
| | | | 2 | .58 | 6.7 | 634 | 7,323 | 86.58 | 5 |
| | C | | 3 | .08 | 5.0 | 87 | 5,465 | 15.92 | 2 |
| | | | 4 | .62 | 6.5 | 678 | 7,104 | 95.44 | 6 |
| | Total area | 19,752 | | | | | | | |

*(con.)*

Table 15.--*(con.)*

SPECIAL LAND

| Avail. class | Prod. class | Area (1) | Mgt. level (2) | Annual mgt. cost per acre (3) | Annual yield per acre (4) | Management cost per year (3) x (1) (5) | Yield expected per year (4) x (1) (6) | Cost per M cubic feet (5) : (6) (7) | Rank (8) |
|---|---|---|---|---|---|---|---|---|---|
| | *$Ft^3/a/yr$* | *Acres* | | *$* | *$Ft^3$* | *$* | *$Ft^3$* | *$* | |
| IV | 20-35 | 13,732 | 1 | | | | | | |
| | | | 2 | | | | | | |
| | A | | 3 | | | | | | |
| | | | 4 | | | | | | |
| | 36-50 | 2,216 | 1 | | | | | | |
| | | | 2 | | | | | | |
| | B | | 3 | | | | | | |
| | | | 4 | | | | | | |
| | 50+ | 836 | 1 | | | | | | |
| | | | 2 | | | | | | |
| | C | | 3 | | | | | | |
| | | | 4 | | | | | | |
| | Total area | 16,784 | | | | | | | |
| | | Σ | | | | | | | |
| | | 51,044 | | | | | | | |

AZTEC LANDS (NO YIELDS AVAILABLE)

Table 16.--*Area and expected costs and yields by productivity class*

MARGINAL LAND

| Avail. class | Prod. class | Area (1) | Mgt. level (2) | Annual mgt. cost per acre (3) | Annual yield per acre (4) | Management cost per year (3) x (1) (5) | Yield expected per year (4) x (1) (6) | Cost per M cubic feet (5) : (6) (7) | Rank (8) |
|---|---|---|---|---|---|---|---|---|---|
| | *$Ft^3$/a/yr* | *Acres* | | *$* | *$Ft^3$* | *$* | *$Ft^3$* | *$* | |
| I | 20-35 | 19,129 | 1 | 0 | 15.6 | 0 | 298,412 | 0 | 1 |
| | | | 2 | 1.25 | 24.0 | 23,911 | 459,096 | 52.08 | 9 |
| | A[1] | | 3 | .67 | 21.1 | 12,816 | 403,622 | 31.75 | 5 |
| | | | 4 | 2.50 | 33.0 | 47,822 | 631,257 | 75.76 | 10 |
| (Inoperable) | 36-50 | 4,553 | 1 | 0 | 31.8 | 0 | 144,785 | 0 | 1 |
| | | | 2 | 1.33 | 39.0 | 6,055 | 177,567 | 34.10 | 6 |
| | B | | 3 | .50 | 38.5 | 2,276 | 175,290 | 12.98 | 3 |
| | | | 4 | 2.42 | 48.0 | 11,018 | 218,544 | 50.42 | 8 |
| | 50+ | 2,047 | 1 | 0 | 48.2 | 0 | 98,665 | 0 | 1 |
| | | | 2 | 1.42 | 61.1 | 2,907 | 125,072 | 23.24 | 4 |
| | C | | 3 | .33 | 50.4 | 676 | 103,169 | 6.55 | 2 |
| | | | 4 | 2.33 | 65.0 | 4,770 | 133,055 | 35.85 | 7 |
| | Total area | 25,729 | | | | | | | |

[1] See table 3, footnote 2.

*(con.)*

Table 16.--*(con.)*

MARGINAL LAND

| Avail. class | Prod. class | Area (1) | Mgt. level (2) | Annual mgt. cost per acre (3) | Annual yield per acre (4) | Management cost per year (3) x (1) (5) | Yield expected per year (4) x (1) (6) | Cost per M cubic feet (5) ÷ (6) (7) | Rank (8) |
|---|---|---|---|---|---|---|---|---|---|
| | *$Ft^3$/a/yr* | *Acres* | | *$* | *$Ft^3$* | *$* | *$Ft^3$* | *$* | |
| V | 20-35 | 2,365 | 1 | 0 | 6.8 | 0 | 16,082 | 0 | 1 |
| | | | 2 | 1.25 | 11.3 | 2,956 | 26,724 | 110.61 | 9 |
| | A | | 3 | .67 | 9.8 | 1,585 | 23,177 | 68.39 | 5 |
| | | | 4 | 2.50 | 16.5 | 5,912 | 39,022 | 151.50 | 10 |
| (Steep slope) | 36-50 | 535 | 1 | 0 | 14.0 | 0 | 7,490 | 0 | 1 |
| | | | 2 | 1.33 | 17.4 | 712 | 9,309 | 76.49 | 7 |
| | B | | 3 | .50 | 18.9 | 268 | 10,112 | 26.50 | 3 |
| | | | 4 | 2.42 | 24.0 | 1,295 | 12,840 | 100.86 | 8 |
| | 50+ | 245 | 1 | 0 | 23.3 | 0 | 5,708 | 0 | 1 |
| | | | 2 | 1.42 | 29.2 | 348 | 7,154 | 48.64 | 4 |
| | C | | 3 | .33 | 25.6 | 81 | 6,272 | 12.91 | 2 |
| | | | 4 | 2.33 | 32.5 | 571 | 7,962 | 71.72 | 6 |
| | Total area | 3,145 | | | | | | | |
| | | Σ 28,874 | | | | | | | |

Table 17.--*Basal area per acre by diameter class and land-productivity class for existing stands and average managed stand*

| Diameter class | Existing stands | | | Average managed stand | | |
|---|---|---|---|---|---|---|
| | Productivity class | | | Productivity class | | |
| | 20-35 | 36-50 | 50+ | 20-35 | 36-50 | 50+ |
| | *Ft*$^2$ | | | | | |
| 2 | 3.9 | 7.5 | 4.9 | 2.0 | 2.6 | 3.0 |
| 4 | 5.4 | 10.5 | 7.0 | 5.5 | 7.1 | 8.2 |
| 6 | 4.8 | 10.7 | 7.9 | 8.0 | 10.5 | 12.4 |
| 8 | 4.2 | 9.3 | 5.1 | 9.5 | 12.6 | 14.9 |
| 10 | 4.2 | 6.1 | 8.0 | 10.2 | 13.7 | 15.9 |
| 12 | 4.4 | 6.6 | 5.8 | 9.8 | 13.2 | 15.3 |
| 14 | 3.8 | 4.5 | 3.9 | 9.3 | 12.0 | 14.1 |
| 16 | 3.7 | 3.9 | 3.6 | 8.3 | 10.3 | 12.4 |
| 18 | 3.6 | 4.9 | 4.5 | 7.1 | 8.6 | 10.6 |
| 20 | 3.8 | 3.0 | 4.0 | 5.7 | 7.4 | 8.9 |
| 22 | 3.9 | 7.4 | 5.8 | 4.7 | 6.2 | 7.2 |
| 24 | 2.8 | 4.4 | 4.6 | 3.7 | 5.0 | 5.8 |
| 26 | 2.2 | 4.1 | 4.1 | 1.8 | 2.9 | 2.7 |
| 28 | 1.2 | 2.4 | 4.7 | 1.2 | 1.3 | 2.2 |
| 30+ | 1.7 | 5.0 | 13.1 | 0 | 0 | 1.7 |
| Total | 53.6 | 90.3 | 87.0 | 86.8 | 113.4 | 135.3 |

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Green, Alan W.
1976. Assessing the timber resource situation on a working circle using inventory data. USDA For. Serv. Res. Pap. INT-183, 43 p. Intermountain Forest & Range Experiment Station, Ogden, Utah 84401.

Realistic projections of timber supplies require knowledge about the land's wood-growing capacity, constraints on the use of forest land for timber production, and the extent and condition of the existing timber resource. Timber inventory data can be used to estimate potential available output and to assess the existing resource in terms of general management needs and of its performance in producing usable wood.

OXFORD: 624; 905.2
KEYWORDS: timber management planning, forest resources, timber inventory, potential timber output

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AMERICAN REVOLUTION BICENTENNIAL
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